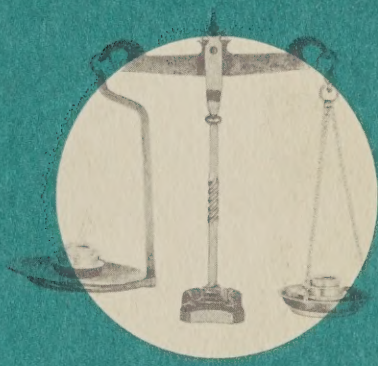
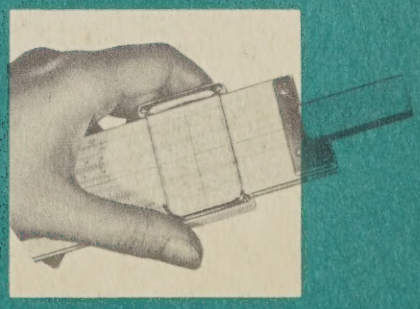


Stainless Steel in Product Design



American Iron and Steel Institute

Standard types of stainless steels

June, 1955

Stainless Steel in Product Design

Committee of Stainless Steel Producers
American Iron and Steel Institute

AISI Type No.	COMPOSITION (Per Cent)								REMARKS
	Cr	Ni	C	Mn	Si	P	S	Other	
201	16-18	3.5-5.5	.15 max.	5.5-7.5	1 max.	.06 max.	.03 max.	N .25 max.	Low-nickel equivalent of Type 301
202	17-19	4-6	.15 max.	7.5-10	1 max.	.06 max.	.03 max.	N .25 max.	Low-nickel equivalent of Type 302
301	16-18	6-8	.15 max.	2 max.	1 max.	.045 max.	.03 max.		High Work-hardening
302	17-19	8-10	.15 max.	2 max.	1 max.	.045 max.	.03 max.		General-Purpose "18-8"
302B	17-19	8-10	.15 max.	2 max.	2-3	.045 max.	.03 max.		More Scaling Resistance Than Type 302
303	17-19	8-10	.15 max.	2 max.	1 max.	.2 max.	.15 min.	.6 Mo or .6 Zr optional	Free Machining "18-8"—Heavy Cuts
303Se	17-19	8-10	.15 max.	2 max.	1 max.	.2 max.	.06 max.	Se .15 min.	Free Machining "18-8"—Light Cuts
304	18-20	8-12	.08 max.	2 max.	1 max.	.045 max.	.03 max.		Low-Carbon—For Welding
304L	18-20	8-12	.03 max.	2 max.	1 max.	.045 max.	.03 max.		Lower-Carbon—For Welding
305	17-19	10-13	.12 max.	2 max.	1 max.	.045 max.	.03 max.		Lower Work-hardening rate
308	19-21	10-12	.08 max.	2 max.	1 max.	.045 max.	.03 max.		Welding Rod—For Ductility
309	22-24	12-15	.2 max.	2 max.	1 max.	.045 max.	.03 max.		High-temp. Strength and Scaling Resistance
309S	22-24	12-15	.08 max.	2 max.	1 max.	.045 max.	.03 max.		Low-Carbon Type 309—For Welding
310	24-26	19-22	.25 max.	2 max.	1.5 max.	.045 max.	.03 max.		Better High-temp. Strength and Scaling Res.
310S	24-26	19-22	.08 max.	2 max.	1.5 max.	.045 max.	.03 max.		Low-Carbon Type 310—For Welding
314	23-26	19-22	.25 max.	2 max.	1.5-3	.045 max.	.03 max.		Most Scaling Resistant
316	16-18	10-14	.08 max.	2 max.	1 max.	.045 max.	.03 max.	Mo 2-3	Increased Corrosion Resistance
316L	16-18	10-14	.03 max.	2 max.	1 max.	.045 max.	.03 max.	Mo 2-3	Low-Carbon Type 316—For Welding
317	18-20	11-15	.08 max.	2 max.	1 max.	.045 max.	.03 max.	Mo 3-4	More Corrosion Resistance Than Type 316
321	17-19	9-12	.08 max.	2 max.	1 max.	.045 max.	.03 max.	Ti 5xC min.	Stabilized Against Carbide Precipitation
347	17-19	9-13	.08 max.	2 max.	1 max.	.045 max.	.03 max.	Cb+Ta 10XC min.	Stabilized Against Carbide Precipitation
348	17-19	9-13	.08 max.	2 max.	1 max.	.045 max.	.03 max.	Cb+Ta 10XC min. but Ta .1 max.	Stabilized Against Carbide Precipitation
403	11.5-13	—	.15 max.	1 max.	.5 max.	.04 max.	.03 max.		Like Type 410—"Turbine Quality"
405	11.5-14.5	—	.08 max.	1 max.	1 max.	.04 max.	.03 max.	Al .1-.3	Reduced Heat-treat-hardenability
410	11.5-13.5	—	.15 max.	1 max.	1 max.	.04 max.	.03 max.		General-Purpose "12 Cr"
414	11.5-13.5	1.25-2.5	.15 max.	1 max.	1 max.	.04 max.	.03 max.		Better Strength Than Type 410
416	12-14	—	.15 max.	1.25 max.	1 max.	.06 max.	.15 min.	.6 Mo or .6 Zr optional	Free Machining "12 Cr"—Heavy Cuts
416Se			.15 max.	1.25 max.	1 max.	.06 max.	.06 max.	Se .15 min.	Free Machining "12 Cr"—Light Cuts
420	12-14	—	over .15	1 max.	1 max.	.04 max.	.03 max.		Like Type 410—For Higher Hardness
430	14-18	—	.12 max.	1 max.	1 max.	.04 max.	.03 max.		General-Purpose "17 Cr"
430F	14-18	—	.12 max.	1.25 max.	1 max.	.06 max.	.15 min.	.6 Mo or .6 Zr optional	Free Machining "17 Cr"—Heavy Cuts
430F Se	14-18		.12 max.	1.25 max	1 max.	.06 max.	.06 max.	Se .15 min.	Free Machining "17 Cr"—Light Cuts
431	15-17	1.25-2.5	.2 max.	1 max.	1 max.	.04 max.	.03 max.		Hardenable—High Impact Strength
440A	16-18	—	.6-.75	1 max.	1 max.	.04 max.	.03 max.	Mo .75 max.	Higher Hardness Than Type 420
440B	16-18	—	.75-.95	1 max.	1 max.	.04 max.	.03 max.	Mo .75 max.	Higher Hardness Than Type 440A
440C	16-18	—	.95-1.2	1 max.	1 max.	.04 max.	.03 max.	Mo .75 max.	Higher Hardness Than Type 440B
446	23-27	—	.2 max.	1.5 max.	1 max.	.04 max.	.03 max.	N .25 max.	Scaling Resistance At Elev. Temp.

		GENERAL PURPOSE			FREE MACHINING			CORROSION RESISTANCE
		302	430	410	303	430 F	416	316
Composition Per cent	Chromium	17-19	14-18	11.5-13.5	17-19	14-18	12-14	16-18
	Nickel	8-10	—	—	8-10	—	—	10-14
	Carbon	.15 Max	.12 Max	.15 Max	.15 Max	.12 Max	.15 Max	.08 Max
	Manganese	2 Max	1 Max	1 Max	2 Max	1.25 Max	1.25 Max	2 Max
	Silicon	1 Max	1 Max	1 Max	1 Max	1 Max	1 Max	1 Max
	Phosphorus	.045 Max	.04 Max	.04 Max	.2 Max	.06 Max	.06 Max	.045 Max
	Sulfur	.03 Max	.03 Max	.03 Max	.15 Min	.15 Min	.15 Min	.03 Max
	Other				.6 Mo or .6 Zr optional	.6 Mo or .6 Zr optional	.6 Mo or .6 Zr optional	Mo 2-3
Sheets & Strip (Annealed)	Tensile Strength, Psi	90,000	75,000	65,000				90,000
	Yield Strength, Psi	40,000	45,000	35,000				40,000
	Elongation, Per cent in 2 inches	50	25	25				50
	Rockwell Hardness	B-85	B-80	B-80				B-85
Bars & Plates (Annealed)	Tensile Strength, Psi	85,000	75,000	75,000	90,000	80,000	75,000	80,000
	Yield Strength, Psi	35,000	45,000	40,000	35,000	55,000	40,000	30,000
	Elongation, Per cent in 2 inches	60	30	35	50	25	30	60
	Rockwell Hardness			B-82			B-82	B-78
	Endurance Limit, Psi	34,000	40,000	40,000	35,000	45,000	40,000	38,000
Creep Strengths Psi; Load For 1% Elongation in 10,000 hrs.	1000 F	17,000	8,500	9,200				25,000
	1100 F	12,000	4,300	4,200				18,200
	1200 F	7,000	2,200	2,000				12,700
	1300 F	4,000	1,300	1,000				7,900
	1500 F	1,200	—	—				2,800
Temperatures, Degrees F	Initial Forging	2100-2300	1900-2050	2000-2200	2100-2350	1950-2100	2100-2300	2100-2300
	Annealing	1850-2050		1500-1650	1850-2050		1500-1650	
	Low Anneal		1400-1500	1200-1400		1250-1400	1200-1400	1850-2050
	Hardening			1700-1850			1700-1850	
	Tempering			400-1400			400-1400	
	Stabilizing							
	Stress-Relief Anneal	400-750			400-750			400-750
	Melting Range	2550-2590	2600-2750	2700-2790	2550-2590	2600-2750	2700-2790	2500-2550
	Max. Continuous Service in Air	1700	1500	1300	1700	1550	1250	1700
	Max. Intermittent Service in Air	1600	1600	1500	1400	1600	1400	1600
Miscellaneous Physical Properties	Modulus of Elasticity Tension, Psi	28×10^6	29×10^6	29×10^6	28×10^6	29×10^6	29×10^6	28×10^6
	Torsion, Psi							
	Density, lbs./cu.in	.29	.28	.28	.29	.28	.28	.29
	Specific Electrical Resistance, Microhms/cm/cm²	72	60	57	72	60	57	74
	Specific Heat Btu/lb./Deg. F	.12	.11	.11	.12	.11	.11	.12
	Thermal Conductivity Btu/Hr./Sq.Ft./Ft./Deg. F.	9.4	15.1	14.4	9.4	15.1	14.4	9.4
	Mean Coeffcient of Expansion							
	32—212F	9.6×10^{-6}	5.8×10^{-6}	5.5×10^{-6}	9.6×10^{-6}	5.8×10^{-6}	5.5×10^{-6}	8.9×10^{-6}
	32—600F	9.9×10^{-6}	6.1×10^{-6}	5.6×10^{-6}	9.9×10^{-6}	6.1×10^{-6}	5.6×10^{-6}	9.0×10^{-6}
	32—1000F	10.2×10^{-6}	6.3×10^{-6}	6.4×10^{-6}	10.2×10^{-6}	6.3×10^{-6}	6.4×10^{-6}	9.7×10^{-6}
	32—1200F	10.4×10^{-6}	6.6×10^{-6}	6.5×10^{-6}	10.4×10^{-6}	6.6×10^{-6}	6.5×10^{-6}	10.3×10^{-6}
	32—1500F		6.9×10^{-6}			6.9×10^{-6}		11.1×10^{-6}

MODIFIED FOR WELDING				ELEVATED TEMPERATURES		COLD WORKING	HARDENABLE BY HEAT TREATMENT			
304	**321**	**347**	**405**	**310**	**446**	**301**	**420**	**440 A**	**440 B**	**440 C**
18-20 8-12 .08 Max 2 Max 1 Max .045 Max .03 Max	17-19 9-12 .08 Max 2 Max 1 Max .045 Max .03 Max Ti 5xC Min	17-19 9-13 .08 Max 2 Max 1 Max .045 Max .03 Max Cb 10xC Min	11.5-14.5 — .08 Max 1 Max 1 Max .04 Max .03 Max Al .1-.3	24-26 19-22 .25 Max 2 Max 1.5 Max .045 Max .03 Max	23-27 — .2 Max 1.5 Max 1 Max .04 Max .03 Max N .25 Max	16-18 6-8 .15 Max 2 Max 1 Max .045 Max .03 Max	12-14 — Over .15 1 Max 1 Max .04 Max .03 Max	16-18 — .60-.75 1 Max 1 Max .04 Max .03 Max Mo .75 Max	16-18 — .75-.95 1 Max 1 Max .04 Max .03 Max Mo .75 Max	16-18 — .95-1.2 1 Max 1 Max .04 Max .03 Max Mo .75 Max
85,000 35,000 50 B-80	90,000 35,000 50 B-80	95,000 40,000 45 B-85	65,000 40,000 25 B-75	95,000 45,000 45 B-85	80,000 50,000 20 B-83	110,000 40,000 60 B-85				
85,000 35,000 60 34,000	85,000 35,000 55 38,000	90,000 35,000 50 39,000	70,000 40,000 30	95,000 45,000 50 B-89	80,000 50,000 25 B-86 47,000	105,000 40,000 55 39,000	95,000 50,000 25 B-92	105,000 60,000 20 B-95	107,000 62,000 18 B-96	110,000 65,000 14 B-97
17,000 12,000 7,000 4,000 1,200	18,000 13,000 8,000 4,500 850	19,000 14,000 8,200 4,600 1,500		17,000 13,000 9,000 5,000 1,000	6,000 3,000 1,500 700 300					
2100-2300 1850-2050 400-750 2550-2650	2100-2300 1750-1950 1550-1650 400-750 2550-2600	2100-2300 1850-2050 1550-1650 400-750 2550-2600	1950-2050 1350-1500 2700-2790	2000-2250 1900-2100 400-750 2550-2650	1950-2050 1450-1600 2600-2750	2100-2300 1850-2050 400-750 2550-2590	2000-2200 1550-1650 1350-1450 1800-1900 300-700 2650-2750	1900-2200 1550-1650 1350-1450 1850-1950 300-800 2500-2750	1900-2150 1550-1650 1350-1450 1850-1950 300-800 2500-2750	1900-2100 1550-1650 1350-1450 1850-1950 300-800 2500-2700
1700	1700	1700	1300	2100	2000	1700	1200	1400	1400	1400
1600	1600	1600	1500	1900	2150	1600	1400	1500	1500	1500
28×10^6 .29 72 .12 9.4 9.6×10^{-6} 9.9×10^{-6} 10.2×10^{-6} 10.4×10^{-6}	28×10^6 .29 72 .12 9.3 9.3×10^{-6} 9.5×10^{-6} 10.3×10^{-6} 10.7×10^{-6} 11.2×10^{-6}	28×10^6 .29 73 .12 9.3 9.3×10^{-6} 9.5×10^{-6} 10.3×10^{-6} 10.6×10^{-6} 11.1×10^{-6}	29×10^6 .28 60 .11 6.0×10^{-6} 6.4×10^{-6} 6.7×10^{-6} 7.5×10^{-6}	29×10^6 .29 78 .12 8.0 8.0×10^{-6} 9.0×10^{-6} 9.4×10^{-6} 9.7×10^{-6}	29×10^6 .27 67 .12 12.1 5.8×10^{-6} 6.0×10^{-6} 6.2×10^{-6} 6.4×10^{-6}	28×10^6 .29 72 .12 9.4 9.4×10^{-6} 9.5×10^{-6} 10.1×10^{-6} 10.4×10^{-6}	29×10^6 11.7×10^6 .28 55 .11 14.4 5.7×10^{-6} 6.0×10^{-6} 6.5×10^{-6} 6.8×10^{-6}	29×10^6 .28 60 .11 14.0 5.6×10^{-6}	29×10^6 .28 60 .11 14.0 5.6×10^{-6}	29×10^6 .28 60 .11 14.0 5.6×10^{-6}

WEIGHTS OF SHEETS, STRIP AND PLATE

Gauge No.	Thickness inches	Weight, Pounds per Square Foot	
		300 Series Cr-Ni	400 Series Cr
—	.375	15.65	15.11
—	.250	10.42	10.09
7	.187	7.81	7.54
8	.172	7.19	6.93
9	.156	6.52	6.29
10	.141	5.89	5.69
11	.125	5.22	5.04
12	.109	4.56	4.40
14	.078	3.26	3.15
16	.062	2.59	2.50
18	.050	2.09	2.02
20	.037	1.54	1.49
22	.031	1.29	1.25
24	.025	1.04	1.01
26	.019	0.79	0.76
28	.016	0.67	0.64
30	.012	0.50	0.48
32	.010	0.42	0.40

WEIGHTS OF TUBULAR PRODUCTS

Outside Diameter	Wall Thickness	Weight, Pounds Per Foot	
		300 Series Cr-Ni	400 Series Cr
⅛	.010	.0124	.0119
	.018	.0208	.0201
	.035	.0359	.0328
3/16	.010	.0192	.0185
	.018	.0330	.0320
	.035	.0577	.0565
¼	.010	.0258	.0248
	.032	.0752	.0723
	.065	.1296	.1246
⅜	.010	.0394	.0381
	.032	.1183	.1150
	.065	.2172	.2100
½	.010	.0528	.0519
	.032	.1614	.1593
	.065	.3040	.3001
¾	.010	.0797	.0770
	.065	.4800	.4634
	.095	.6709	.6470
1	.010	.1067	.1031
	.058	.5890	.5663
	.109	1.047	1.010
1¼	.014	.1865	.1802
	.065	.8304	.8021
	.141	1.686	1.626
1½	.014	.2243	.2165
	.072	1.108	1.070
	.141	2.065	1.994
1¾	.022	.4248	.4098
	.109	1.928	1.860
	.141	2.446	2.354
2	.022	.4692	.4524
	.109	2.222	2.144
	.148	2.955	2.805
2½	.028	.7462	.7349
	.109	2.809	2.707
	.165	4.153	4.007
3	.035	1.118	1.080
	.125	3.874	3.741
	.156	4.783	4.615

ALLOY CASTINGS INSTITUTE STAINLESS ALLOY DESIGNATIONS

Cast Alloy Designation	Wrought Alloy Type	Composition (per cent)							
		C	Mn max.	Si max.	P max.	S max.	Cr	Ni	Other Elements
CA-15	410	0.15 max.	1.00	1.50	0.04	0.04	11.5-14	1 max.	Mo 0.5 max.
CA-40	420	0.20-0.40	1.00	1.50	0.04	0.04	11.5-14	1 max.	Mo 0.5 max.
CB-30	431	0.30 max.	1.00	1.00	0.04	0.04	18-22	2 max.	—
CC-50	446	0.50 max.	1.00	1.00	0.04	0.04	26-30	4 max.	—
CE-30	—	0.30 max.	1.50	2.00	0.04	0.04	26-30	8-11	—
CF-8	304	0.08 max.	1.50	2.00	0.04	0.04	18-21	8-11	—
CF-20	302	0.20 max.	1.50	2.00	0.04	0.04	18-21	8-11	—
CF-8M	316	0.08 max.	1.50	1.50	0.04	0.04	18-21	9-12	Mo 2.0-3.0
CF-12M	316	0.12 max.	1.50	1.50	0.04	0.04	18-21	9-12	Mo 2.0-3.0
CF-8C	347	0.08 max.	1.50	2.00	0.04	0.04	18-21	9-12	Cb 8xC min., 1.0 max., or Cb-Ta 10xC min., 1.35 max.
CF-16F	303	0.16 max.	1.50	2.00	0.17	0.04	18-21	9-12	Mo 1.5 max., Se 0.20-0.35
CH-20	309	0.20 max.	1.50	2.00	0.04	0.04	22-26	12-15	—
CK-20	310	0.20 max.	1.50	2.00	0.04	0.04	23-27	19-22	—
CN-7M	—	0.07 max.	1.50		0.04	0.04	18-22	21-31	Mo-Cu
HA	—	0.20 max.	0.35-0.65	1.00	0.04	0.04	8-10	—	Mo 0.90-1.20
HC	446	0.50 max.	1.00	2.00	0.04	0.04	26-30	4 max.	Mo 0.5 max.
HD	327	0.50 max.	1.50	2.00	0.04	0.04	26-30	4-7	Mo 0.5 max.
HE	—	0.20-0.50	2.00	2.00	0.04	0.04	26-30	8-11	Mo 0.5 max.
HF	302B	0.20-0.40	2.00	2.00	0.04	0.04	19-23	9-12	Mo 0.5 max.
HH	309	0.20-0.50	2.00	2.00	0.04	0.04	24-28	11-14	Mo 0.5 max.
HI	—	0.20-0.50	2.00	2.00	0.04	0.04	26-30	14-18	Mo 0.5 max.
HK	310	0.20-0.60	2.00	3.00	0.04	0.04	24-28	18-22	Mo 0.5 max.
HL	—	0.20-0.60	2.00	3.00	0.04	0.04	28-32	18-22	Mo 0.5 max.
HN	—	0.20-0.50	2.00	2.00	0.04	0.04	19-23	23-27	Mo 0.5 max.
HT	—	0.35-0.75	2.00	2.50	0.04	0.04	13-17	33-37	Mo 0.5 max.
HU	—	0.35-0.75	2.00	2.50	0.04	0.04	17-21	37-41	Mo 0.5 max.
HW	—	0.35-0.75	2.00	2.50	0.04	0.04	10-14	58-62	Mo 0.5 max.
HX	—	0.35-0.75	2.00	2.50	0.04	0.04	15-19	64-68	Mo 0.5 max.

When wrought and cast alloys are both used, this table helps to compare the wrought and cast forms. However, chemical differences do exist and each form should be ordered according to the system designated for that form.

Cast alloy designations beginning with the letter C are intended primarily for corrosion resistant applications at temperatures below 1200 F; the letter H means alloys intended for use above 1200 F. The second letter refers to the Cr-Ni content, increasing from A to X.

STANDARD MILL FINISHES STAINLESS STEEL

No.	Description
1	Annealed and pickled; frosty and bright.
2D	Dull cold rolled, annealed and pickled.
2B	Bright rolled after annealing and pickling. Very reflective but less uniform than textures obtained with abrasives.
4	Standard polished surface; with "grain" produced by direction of belt or wheel.
6	Soft lustrous texture imparted by tampico brushing after No. 4 polishing; low reflectivity and high uniformity.
7	Commercial mirror finish obtained with fine abrasives.
8	Mirror polish smoother than No. 7; available on special order only.
1 STRIP	Cold rolled annealed and pickled; frosty and bright.
2 STRIP	Similar to 2B sheet finish.
NOTE	Though only two finishes are designated for strip, strip stock can always be ordered cut to lengths and supplied with regular sheet finishes.

Practical examples show WHERE...WHEN...HOW... Stainless improves design

This book is for product designers, engineers and industrial designers. It is about stainless steel as a designer's material.

Along with useful engineering data, these pages contain case histories that illustrate—in a practical way—where and how stainless has been used successfully. None of the products shown are theoretical. They have all been made and sold commercially.

Selecting materials is one of the most important parts of the designer's job. The technical reasons for his choice may sometimes be found in mechanical or corrosion-resistance requirements of the product. On the other hand, an equally valid technical choice may be based on buyer attitudes and sales appeals.

Stainless is selected for both reasons. It offers a combination of mechanical, heat-resisting and corrosion-resisting properties, no other commercial metal can match. At the same time, it is a "glamour" material. Stainless trim that may add little or nothing to a product's function will, nevertheless, help it sell in competition.

Actual benefits to be gained are analyzed in the following pages, and possible alternatives are considered. This book outlines where and how to use stainless steel so that it more than justifies its cost.

Committee of Stainless Steel Producers
American Iron and Steel Institute
350 Fifth Avenue, New York 1, N. Y.

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Remove Design Limitations	40

What stainless steel means to people who have

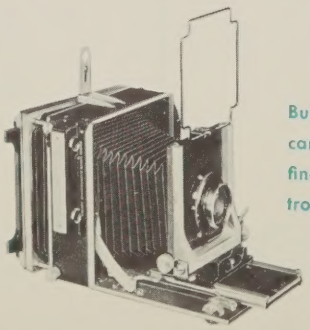
Here a stainless case for a hand fire extinguisher immediately gives an impression of quality and reliability.

Housewives now know that many things they use in their kitchens—besides pots and pans—are best made of stainless steel.

SUGGEST QUALITY. People know that stainless is a premium material. Salespeople can be educated to point out its presence in the product as evidence of quality.

FINEST FOR FOOD. Women pay more for stainless kitchenware, and they like to use it. Restaurant operators invest in all-stainless kitchens—the most economical in the long run.

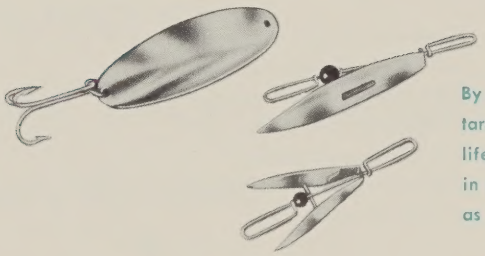
BRIGHTWORK AIDS SALES. Makers of automobiles and appliances know that stainless trim attracts buyers. If the trim can be designed to be functional too, so much the better.



Buyers of fine products like cameras associate stainless with fine workmanship and with trouble-free service.

The designer who wants to gain a competitive edge for his product can take advantage of existing consumer attitudes towards stainless steel. Any one or a combination of the following appeals can be effective.

products to sell



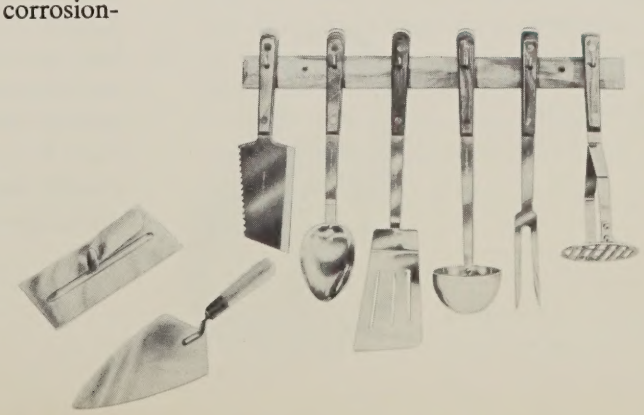
By cutting out loss from tarnishing during shelf-life, stainless saves money in many products such as these fishing lures.

CONSIDER SHELF-LIFE. Stainless can sometimes pay its way merely by keeping the product salable during storage and display periods. Tarnishing and rusting cost money in retail stores and can kill repeat orders.

HIGH STYLE TOO. Designers now recognize the impression stainless steel is creating in fine flatware, holloware and jewelry. It adds a modern note.

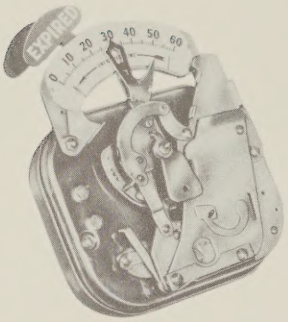
The elegance of high-style holloware is complemented by the nobility of stainless steel.

LASTS A LIFETIME. Billions of dollars are lost to corrosion each year. If you design a thing that's worth keeping, then it's worth the use of corrosion-resisting materials.

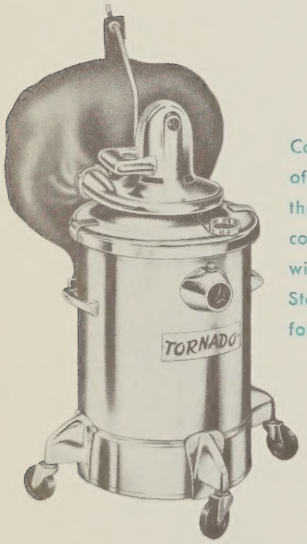


A buyer's eye is attracted by stainless hand tools for garden, for home projects, for kitchen or for play. And the stainless ones perform better, too.

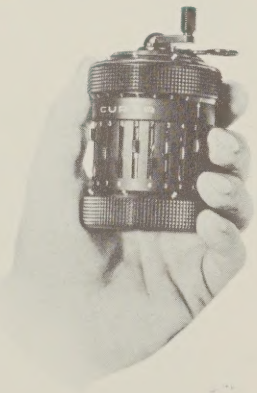
How to decide when to use stainless for "EASY MAINTENANCE"



The mechanism of this parking meter unit, which can be exposed to the weather, is made principally of stainless stampings.



Commercial vacuum cleaners are often used with cleaning solutions that introduce a moisture and corrosion problem along with mechanical abrasion. Stainless is the ideal material for such service.



Precision during a long working life influenced the choice of stainless for parts of a small hand adding machine.

Many sports items are good stainless applications because this material means more fun with less care.

Perspiring hands stain some metals. This lock has a stainless case because its designer wanted to avoid tarnishing caused by people's fingers.

Here are some general questions a designer can ask himself. The answers on the opposite page will help him apply stainless wisely, and the product that results from this approach will be closely related to customers' needs and buying habits.

(1) *How clean,* how smooth, or how handsome does the specific surface have to be? Standards vary widely—sometimes for different parts of a single product. The top of a table, for example, may impose very strict requirements of mar-resistance, cleanliness and clean appearance while the underside of the same table has practically zero appearance requirements. So we must ask—how much of a job will maintenance be required to accomplish?

(2) *Will sanitation or appearance*—or both—be the governing need? Usually, things that have to be immaculate for health's sake are designed for easy cleaning. Then, the alert designer will go on to give them a "clean look" to help them sell and for morale's sake.

(3) *What are the enemies* of good appearance or cleanliness? Common ones are weather, dirt, food, chemicals, decay or pests, water, abrasion, impact and heat. Most products come up against several of these factors. For example, a stove top gets thermal shocks, accidental spilling and burning of food, and abrasive scouring. By contrast, a picture frame, indoors, gets only atmospheric dust; it is seldom handled; and it is practically free from any other hazards.

(4) *Will paint* or some other surface coating be acceptable? Will paint stand up in service? Will it be advantageous? Should the product have several colors?

(5) *How long* should the surface last? How important is economical or trouble-free maintenance to the user? Can "easy maintenance" be featured to help sales? Will replacement costs and annoyance, if less durable materials are used, impair the salability or usefulness of the product?

Play equipment should not cause cuts, snag clothing nor stain children's garments. It is often cheaper to assure safety and cleanliness standards by using stainless than by constant cleaning, painting and repairing.

WHEN and WHERE

Stainless pays its way in easy maintenance

The overwhelming majority of metal products sold in this country today are made of painted mild steel. Some are porcelain enameled, and some are plated with other metals. Obviously, they must meet their maintenance requirements, or they would soon be forced out of a competitive market.

Where, then, does stainless steel fit in?

The following answers to the questions on the opposite page provide a fairly reliable guide:

(1) Stainless should be specified for any surface that you think should stay hygienically clean, handsome, or very smooth.

(2) Stainless has always been used both for good health and for good appearance. Cleanability is the main requirement in hospitals, commercial kitchens, and in atomic installations, although appearance is undoubtedly a factor too. Products that are sold to consumers, on the other hand, have to look as clean and modern as they really are.

(3) A mild combination of weather, dirt, food chemicals, micro-organisms, water, abrasion, impact and fire can be withstood by coated metals or plastics. More severe conditions require stainless. Here, a designer must weigh performance against whatever extra cost may be entailed. Often a slight addition to cost of material is well justified by the money saved in care, cleaning, repair and replacement throughout a product's service life.

(4) If a painted surface is desirable, stainless is less likely to be needed. There are exceptions—signs, nameplates, marine equipment, etc. If you would like to do without any surface coating whatsoever, stainless is probably the best material you can use.

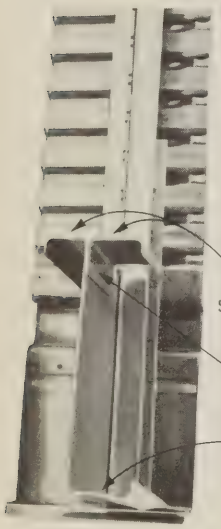
(5) Stainless is durable. It is most useful for products that are kept for some time and used "hard." It would be first choice for a surface that is expected to stand repeated scrubbing and abrasion. Sometimes stainless can be justified for novelties or trinkets too, but not so often. Buyers' habits can be analyzed for an indication of whether they will pay higher first cost to make possible lower long-term costs.

Here is reliable strength when you want to design for high stresses

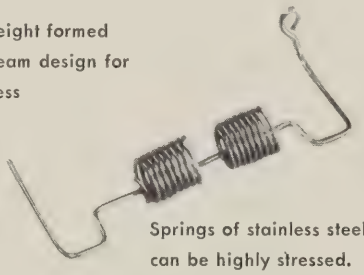
COLD-WORKED PROPERTIES

STATE	TENSILE STRENGTH psi	YIELD STRENGTH psi (OFFSET: 0.2%)	ELONGATION IN 2", %	ROCKWELL HARDNESS	ENDURANCE LIMIT psi	COLD BEND DEGREES
STRIP, TYPE 301						
Annealed	110,000	40,000	60	B-85	35,000	180
¼ hard	125,000*	75,000*	25*	C-25	—	180
½ hard	150,000*	110,000*	18*	C-32	—	180
¾ hard	175,000*	135,000*	12*	C-37	—	90
Full hard	185,000*	140,000*	9*	C-41	80,000	90
STRIP, TYPE 302						
Annealed	90,000	40,000	50	B-85	—	180
¼ hard	125,000*	75,000*	12*	C-25	—	90
½ hard	150,000*	110,000*	8*	C-32	—	90
WIRE, TYPE 302 (.062")						
Soft temper	105,000	35,000	55	—	—	180
Soft bright	125,000	90,000	40	—	—	180
Hard temper	160,000	125,000	20	C-33	—	180
Spring temper	260,000	—	—	—	—	180

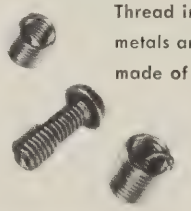
*Minimum—may exceed these values by substantial percentages.
Note: Straightened wire may have slightly higher strengths in soft temper—slightly lower in other tempers.



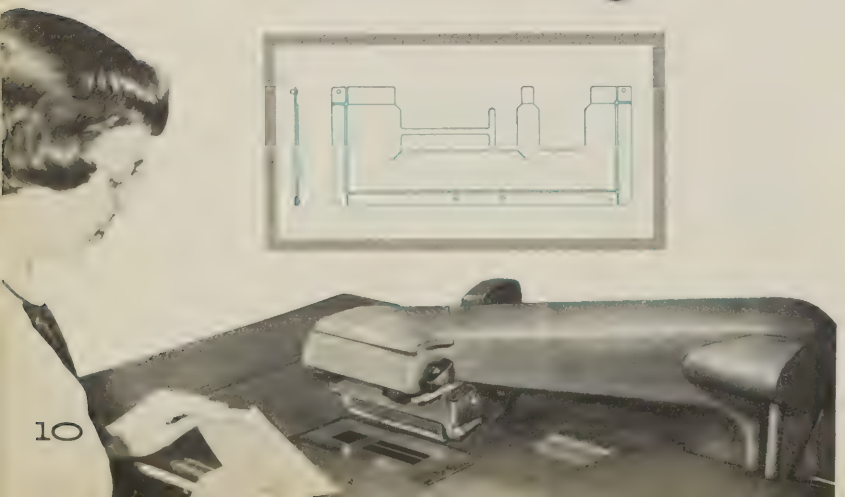
Detail of the lightweight formed and welded floor beam design for a heavy-duty stainless steel highway trailer.



Springs of stainless steel can be highly stressed.



Thread inserts for soft metals and plastics are made of stainless steel.



A flat spring caused frequent breakdowns in this addressing machine until stainless was used—not only to provide the exact tension required — but to resist cracking under constant pounding during the machine's operation.

We use strong materials, of course, so that things won't break in service. This does not mean that a designer always looks for the strongest materials—as the popularity of wood, soft metals, plastics, fabrics, etc. certainly demonstrates. Yet there are times and places where good design calls for great strength, high stresses, and utmost reliability.

Hand tools, portable units, removable parts—all the things that people lift and carry—can usually be designed better if high-strength materials are used. In many cases, this works out in final design with formed or machined parts of stainless for stressed elements and with light-alloy castings or plastics moldings for elements like handles whose size has a relationship to function so that there is no advantage in making them less bulky.

CHROMIUM-NICKEL STAINLESS STEELS can be work-hardened to tremendous strengths. All types of stainless in their annealed states have higher ultimate strengths than ordinary steel. When hardened, they become stronger yet.

One family of heat-treatable stainless steel includes the cutlery grades and turbine steels. These alloys can be hardened by thermal treatments to improve their properties. Detailed information can be obtained from your steel supplier.

Of general interest to all designers is the fact that the 18-8 stainless types can attain strengths of several hundred thousand pounds per square inch when they are cold rolled or cold drawn. Type 301, a 17-7 alloy, displays an even greater tendency to gain strength when cold worked.

For examples of practical uses that have been made of this property, we can turn to transportation equipment. Stressed-skin engine nacelles for airplanes, the structures and skin of high-speed railway cars, and the very best highway truck trailers all use highly cold-worked 17-7 stainless to attain reliable high strength with light weight. They must also resist weathering. The fire resistance that they get from stainless is a design bonus.

You Don't Need Paint To Prevent Corrosion

Stainless needs no coating—no anodic treatment—nothing but occasional cleaning to stay bright.

Designers call for stainless where they want the handsome appearance of plain metal. They use it where bumps, scratches, dropping, abnormal abuse, or the ordinary daily use of the product would soon beat up a protective coat of paint or enamel.

The characteristic appearance of stainless steel depends, of course, on the fact that it does not rust, corrode or discolor. This sets it apart from most other metals. Freedom from rusting is the key to its dense, smooth surface, its cleanability and its glass-like quality where sanitation is paramount.

ALLOY SELECTION Some stainless types resist corrosion better than others. Generally speaking, resistance varies with the percentage of chromium in the composition.

The 18-8 types, with 18 per cent chromium and 8 per cent nickel have grown to be a sort of standard for comparison. These alloys have ample reserve margins of resistance to weather exposure, kitchen, laundry, dairy and general use.

Type 430, containing nominally 17 per cent chromium, serves almost interchangeably with the 18-8 types for many applications. During periods of nickel shortage, when the more-readily-fabricated chromium-nickel types have been in short supply, Type 430 has served successfully as a general-purpose stainless.

Adding molybdenum to chromium-nickel stainless steel increases resistance to salts and acids. Type 316 stainless, the most-used molybdenum-bearing grade is used in general product design for certain seacoast and salt-spray applications.

Exposure of chromium-nickel stainless to temperatures between 800°F and 1600°F tends to decrease its corrosion resistance. Stabilized grades of chromium-nickel stainless and straight-chromium types of stainless are not sensitive to this temperature effect.

SOME THINGS TO AVOID Once he selects stainless steel, the designer of a product can usually forget about corrosion. Metallurgists and chemists have learned, however, that stainless steel can be attacked by certain chemicals. Knowing something of these special problems can be of value to the designer facing an unusual corrosion situation.

The chemical enemies of stainless are the halides —chlorides, fluorides, bromides and iodides, which are reducing agents. These agents deprive stainless of its oxygen. Stainless begins to lose its resistance to corrosion if deprived of oxygen for a long time.

Here is what this means practically. If the metal is rinsed or aired occasionally, it will perform well. On the other hand, if accumulated dirt or foreign matter seals off the air for long periods, and if certain brine concentrations saturate the dirt, there is a strong likelihood of localized pitting under these deposits. Such difficulties have occurred in chemical process equipment. They are rarely encountered in other products, but the remedies that have been worked out by process equipment designers are summarized below for your guidance.

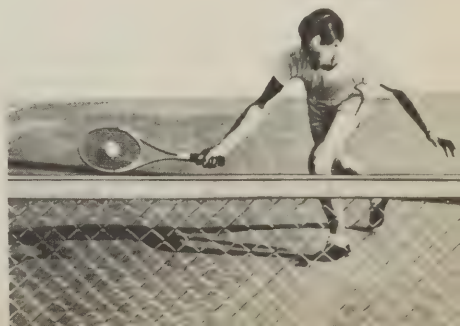
(1) Avoid sharp crevices where dirt may gather. Use rounded corners instead.
(2) Smooth off weld beads by grinding and polishing if corrosive conditions are expected.
(3) Provide for removal and cleaning of intricate things like strainers, baskets, etc.
(4) Call for removal of iron particles and mill scale if necessary after fabrication.
(5) Allow freedom for expansion of members that will be heated in corrosive conditions.
(6) Specify another material—not stainless—where stagnant brines or liquors will settle for long periods of time. However, if the salty location is turbulent or aerated, stainless may be considered.

Simple things like paper clips are better if they don't corrode.

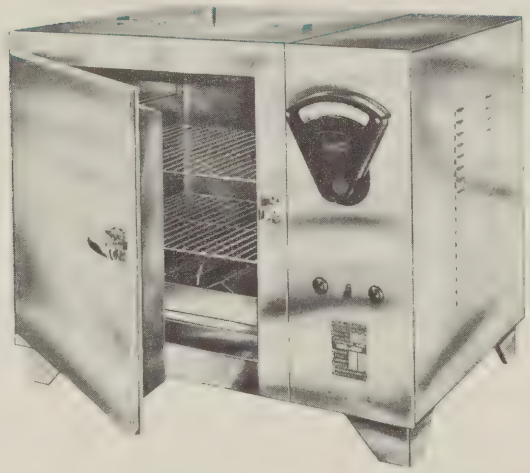
The stainless grid on the top of this burner resists intense heat and the corrosive attack of spilled chemicals.

Stainless cannisters are another instance of cleanliness and non-breakability with a bonus in beauty.

Stainless tennis nets need no maintenance attention whatsoever.



Stainless is good in cold and heat



Both hot and cold boxes of this type are made of stainless steel.

Most ordinary products don't have to operate at hundreds of degrees below zero or at a dull red heat. But many things that do have to endure temperature extremes are made of stainless.

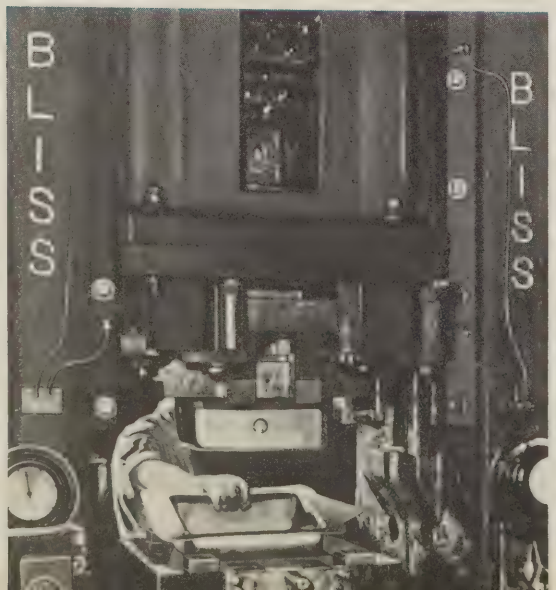
There are definite advantages in selecting stainless steel for more moderate conditions, too. The same characteristics that make it a key material for jet engines lead to its use for fireboxes of furnaces and space heaters.

HOT When metals are heated, they can fail in one of several ways. Limitations that a designer must consider include reduction in ultimate or yield strength, possible reduction of ductility, creep, and scaling which is a progressive oxidation of exposed surfaces. In the ultimate case, of course, melting temperature itself may become a significant limit to consider.

Each of these factors has a bearing on some kinds of high-temperature applications.

For example, high-pressure valves, pumps and pipe fittings designed to operate above 1000F are

Stainless is a material that can be fabricated readily into the design you want



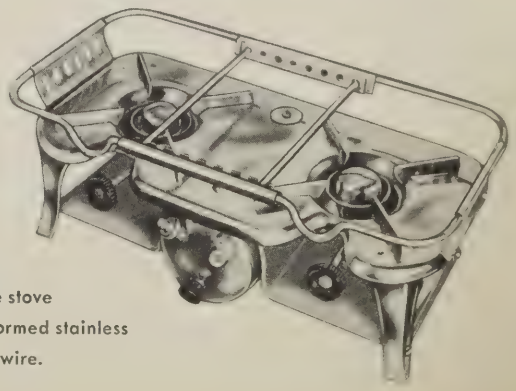
Exceptional ductility makes 18-8 stainless a widely-used deep-drawing material.

Design concepts and material choices usually interact. A designer chooses materials to meet functional and decorative needs. At the same time, the working limitations or possibilities of a material will hold back or advance the goals a designer can reasonably set out to reach.

Stainless advances those goals in almost every instance. Not only does the material perform well in service, it also lends itself to fabrication by a wide variety of standard, economical factory processes.

Intricate details, elaborate forming, deep draws, precise machining and similar requirements need not be avoided in designing stainless parts. Such fabricating requirements do not inflate costs unduly. As a matter of fact, stainless steel can very often be fabricated more intricately or more severly at less added manufacturing cost than other metals.

FORMING The formability of stainless can be described generally in terms of other common



A portable stove made of formed stainless sheet and wire.

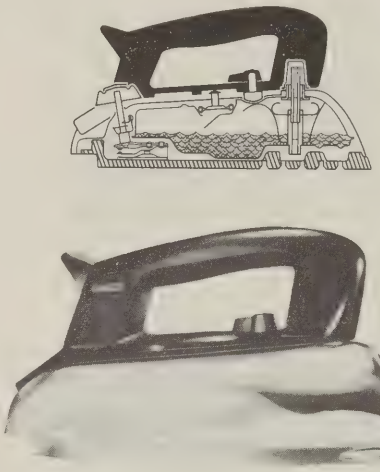
made of stainless for reliable high strength and low creep at these temperatures.

In furnace parts, combustion chambers, flue-liners and the like, the problem is somewhat different. Here stainless finds application because the hard oxide scale that forms on its surfaces does not come off the way the softer scale would on ordinary steel. Stainless endures heat and oxidizing atmospheres that consume other steels quite rapidly as successive layers of scale fall away.

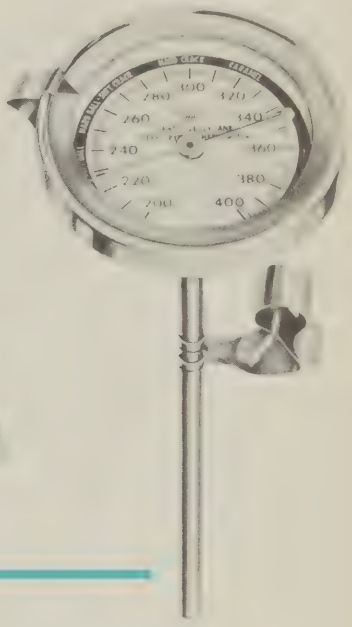
COLD Most metals get brittle as they are chilled. Indeed, this is true of straight-chromium stainless steels. Type 430, for example loses most of its useful ductility at sub-freezing temperatures.

The chromium-nickel types, though, stay strong, ductile and shock resistant clear down to the temperatures of liquid oxygen. They are used commercially at such temperatures—notably for tanks and equipment that would cause considerable damage or injury if they were to fail in service.

Economy dictated making the shell and interior parts of this steam iron of stainless. Corrosion difficulties are avoided, and the exterior needs no plating.



Stainless tubing does an important job on the business end of this immersion thermometer, and other parts are stainless to match.



metals. Stainless is about as ductile as copper or brass, but stronger than ordinary steel. Like the common non-ferrous metals, the chromium-nickel stainless steels grow harder and stronger as they are bent and formed. Stainless can be worked more severely than most metals, but it takes more force, bigger machine tools, greater power, heavier dies, etc. to do the forming.

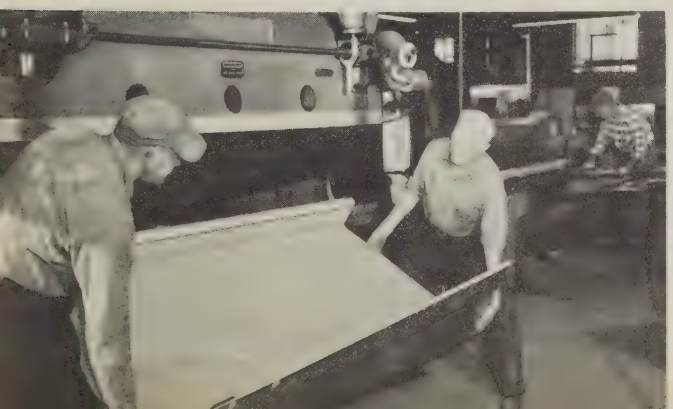
WELDING There never need be any concern about calling for welded stainless construction. All the commercial welding methods work well on stainless if certain precautions are taken. For some kinds of work, arc weld beads are ground smooth and polished. It is then almost impossible to locate the weld by looking at the polished metal surface.

Brazing is employed occasionally. So is soldering —to seal a joint that gets its strength by some other method, such as lock seaming or spot welding.

MACHINING Because most standard types of stainless tend to form tough, stringy chips when machined, free-machining grades have been developed. Parts that will require extensive turning, threading, milling or drilling are generally made of the free-machining stainless in the same family as the rest of the stainless steel that makes up the assembly.

FORGING—CASTING Almost every type of stainless can be hot forged. Many parts to be made of chromium-nickel types, however, are cold formed, inasmuch as these alloys have the ductility to absorb considerable working. The main bulk of stainless forging work is done on 12-per-cent chromium types which are forged into golf club heads and similar parts.

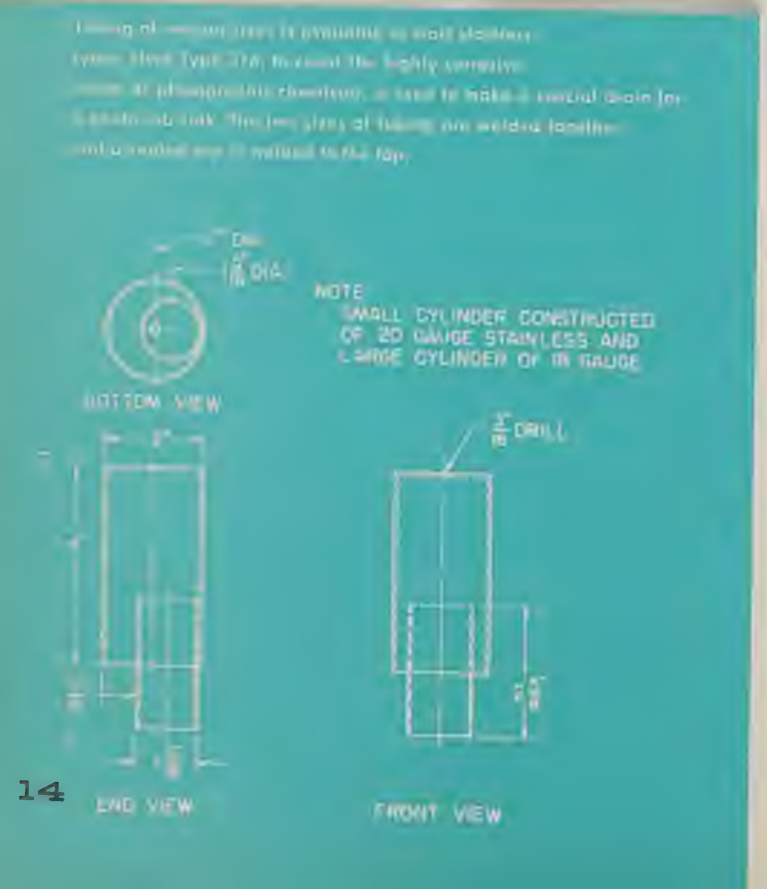
Stainless castings are produced in sizes and shapes required. For economy of weight and metal, it is more common for stainless parts to be fabricated of thin sheet or plate, as the heavier cast sections are seldom required for strength. Also, extra metal will not be needed as a "corrosion allowance."



Press brake forming takes care of the long bends, radii, rolled edges or special sectional contours.

Shallow drawn stainless tops are used on many water-cooler units.

Sizes and shapes of stainless



When other factors are equal, and a designer has a free choice that will affect material size, shape, condition or finish, he naturally chooses the more popular specification. This usually eliminates an extra material cost and almost always makes for better deliveries and availability.

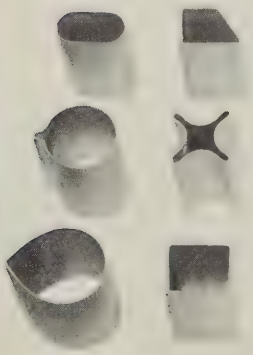
Here are the general facts that should be most useful for a designer to have at hand in order to make such choices:

SHEETS AND STRIP For most work, stainless is purchased as sheets or strip. By steel-mill custom, pieces 2 feet wide and wider are known as sheet—less than 2 feet wide, as strip.

Stainless sheets are available in a variety of polished finishes. Sheets in standard sizes up to 4 to 10 feet are regularly available from warehouse stock. Thicknesses range from 0.016 inch or 28 gauge up to 0.172 inch or 8 gauge. Larger sizes, and thinner sheets down to about 0.001 inch are obtainable on order from mills.

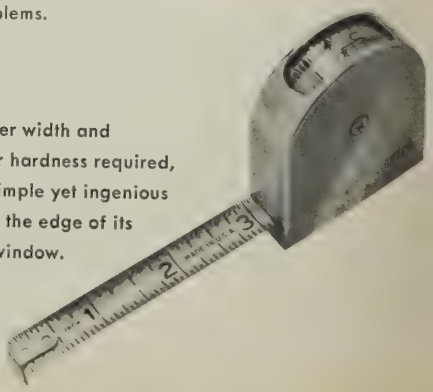
Stainless strip is sold in cut lengths or continuous coils in thickness as small as 0.001 inch.

Some steel-mill operations can be performed more readily on narrow machines than wide ones. This is reflected in differences between the way sheet and strip are specified and sold. Very often, it is possible to gain price, finish, or tolerance advantages by using strip stainless instead of sheet. Availability in long coiled lengths can be advantageous too, if appropriate planning is done at the design stage.



Stainless tube is available, not only round, but in a wide variety of formed shapes that solve individual design problems.

Slitting machines like this make narrow strips economically out of the wider material produced at the steel mill.



Stainless strip, slit to the proper width and rolled to the precise temper or hardness required, is the basic material for this simple yet ingenious rule that can be read either at the edge of its stainless case or through the window.

that are regularly available

PIPE AND TUBING Stainless is pierced and hot rolled or extruded into seamless pipe and tubing. It is also rolled up and welded into pipes and tubes. Both processes result in a high-quality product.

Sizes range from a 36-inch diameter for pulp and process piping, down to a few thousandths of an inch—the stainless tube used for making hypodermic needles.

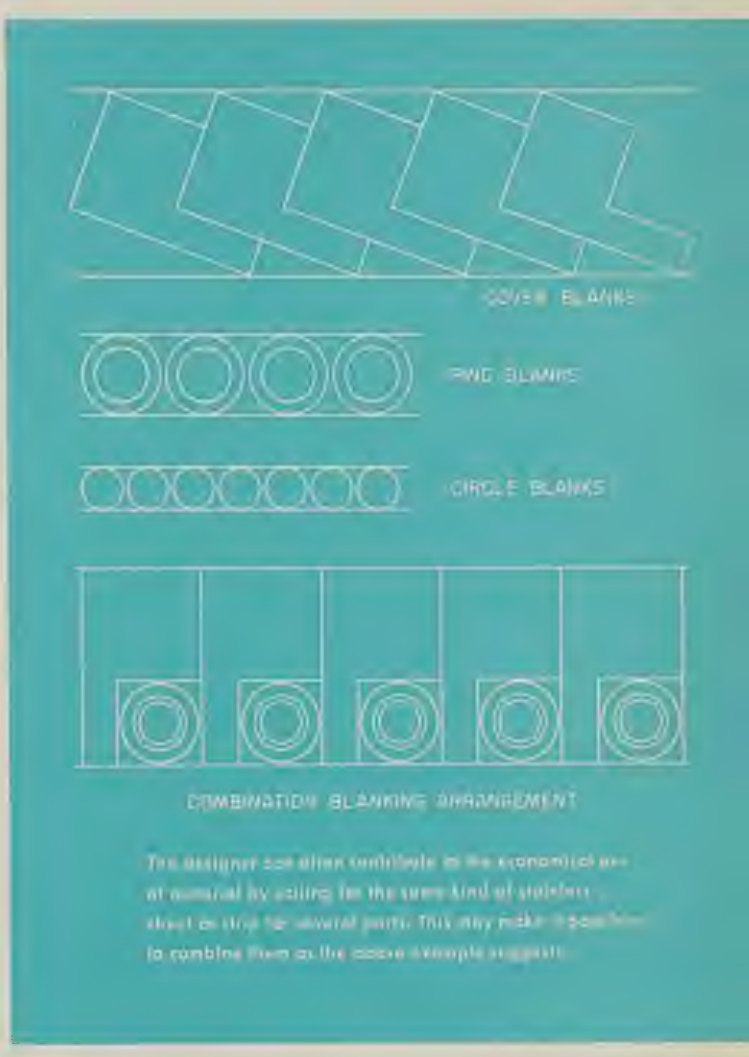
A wide variety of surface finishes can be obtained. Ground or polished finishes are usually specified in terms of grit number. An 80-grit finish gives a coarse, dull surface. At the other end of the scale is a 320-grit finish—the commercial mirror finish.

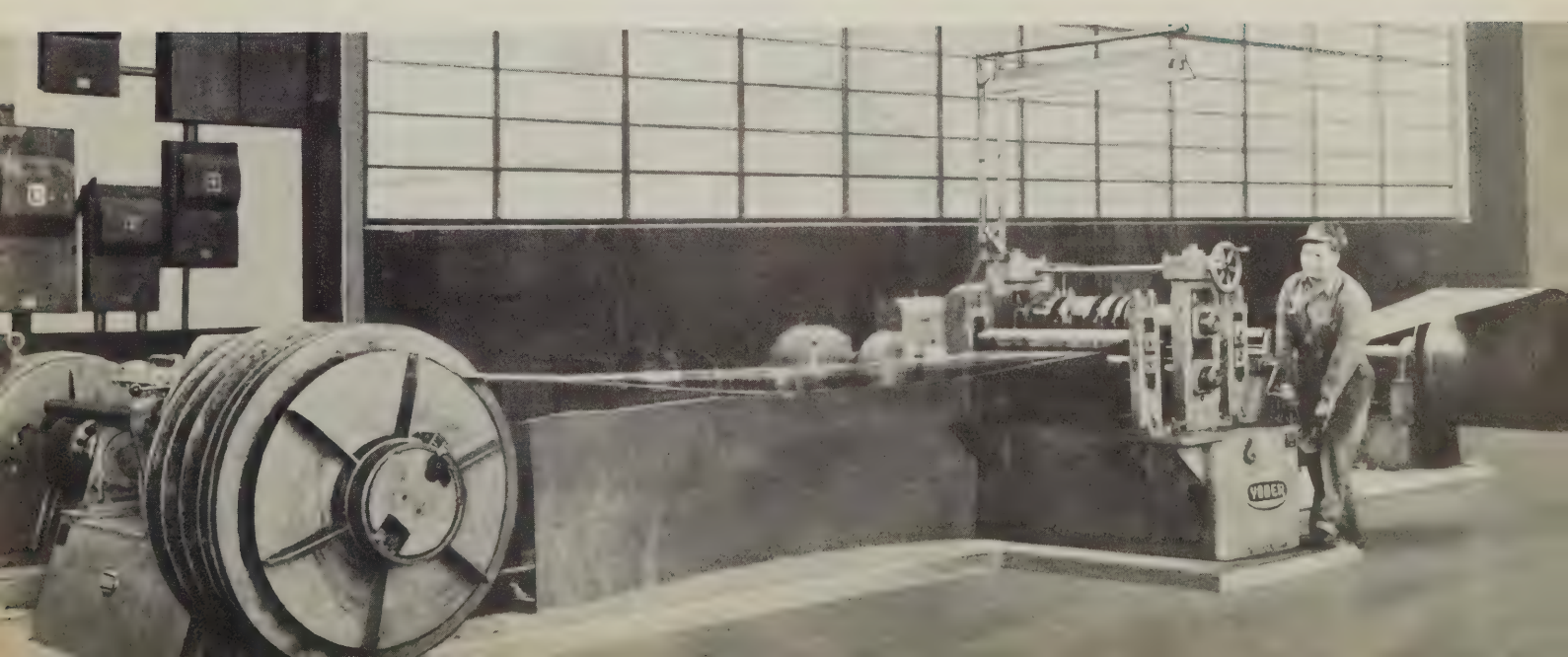
The interior finish varies from sanitary tubing which is mechanically polished inside, to welded ornamental tubing, which has the welding flash left untouched on the inner side.

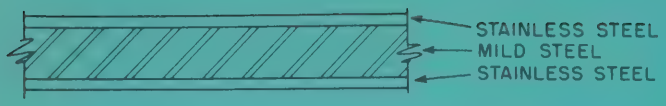
The size of stainless tubing is usually given in terms of outside diameter and wall thickness. From ⅜ to 5 inches, most diameters, by even eighths, are standard in about a dozen wall thicknesses. Stainless is also supplied in standard pipe sizes.

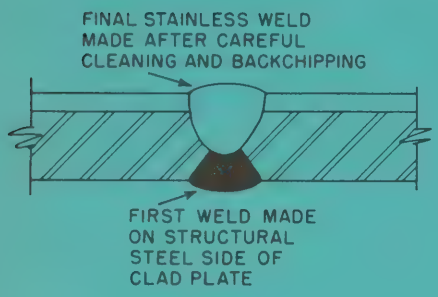
Square, rectangular and specially-shaped tubing sections are readily available in stainless. These are manufactured as round sections. They are often mechanically polished while in cylindrical shape, then drawn or rolled to the required shape.

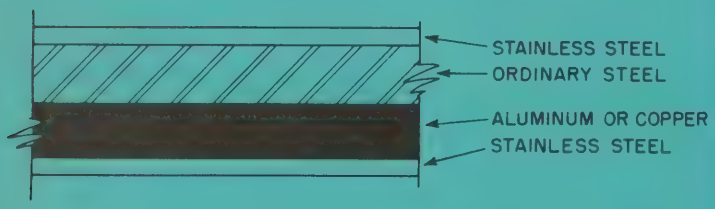
Joints in stainless tubing can be made by welding, brazing or with mechanical fittings.

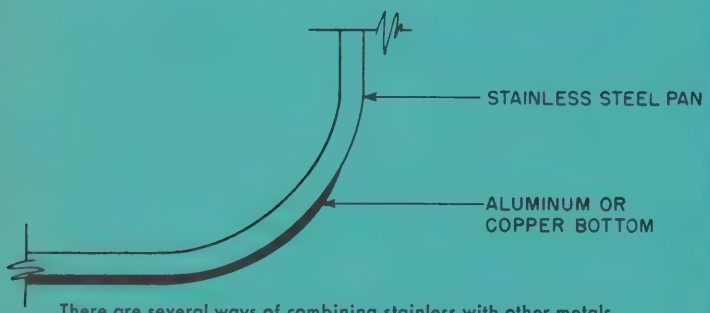












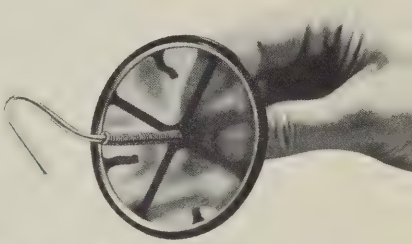
There are several ways of combining stainless with other metals in a "sandwich." Stainless clad steel—a mill product—is shown in the top three diagrams. The welding technique sketched assures continuity of the clad surface in large vessels. Such combinations as the 4-ply assembly and the cooking pan bottom are archieved by special bonding or plating methods in the factory.

PLATES Flats $\frac{3}{16}$ inch and over in thickness are called plate. Stainless and stainless-clad plates can be obtained with one or both sides polished as required. Maximum plate size varies among producers. Whenever very large structures are to be made, the plate sections are butt welded together.

CLAD STAINLESS Many "sandwich" combinations are made with stainless and other metals bonded together to form composite sheets, strip and plates. Clad products of this sort are carefully laminated under welding heat and pressure as relatively heavy pieces at the mill, then rolled down to the required thicknesses. The amount of each metal is expressed as a percentage of the total thickness.

Stainless is commonly clad on one or both sides of mild steel in 10 and 20-percent thicknesses. Generally the same surface finishes are available as with solid stainless.

Two-ply, three-ply and even four-ply combinations of stainless with copper, aluminum or mild steel are used where good heat conductivity is re-



Wire screening as fine as 200-mesh is made of stainless.

Flat stainless bars are formed to make this contemporary chair.

The cookware at left features aluminum bottoms on stainless pans while the pan below has a copper bottom which contributes both heat conduction and a styling accent.

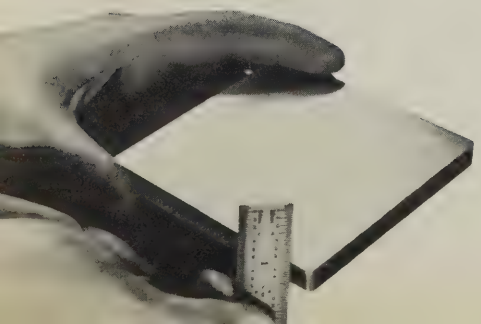
quired along with the cleanability, hardness and corrosion resistance of stainless. Not all these combinations are generally available as mill products.

BARS, WIRE AND SHAPES Bars may be obtained as hot rolled or with the scale removed by pickling or blast cleaning. Cold finished stainless bars come with the bright finish imparted when they are drawn to size during manufacture, or, if they are round, they may be centerless ground or rough turned at the mill.

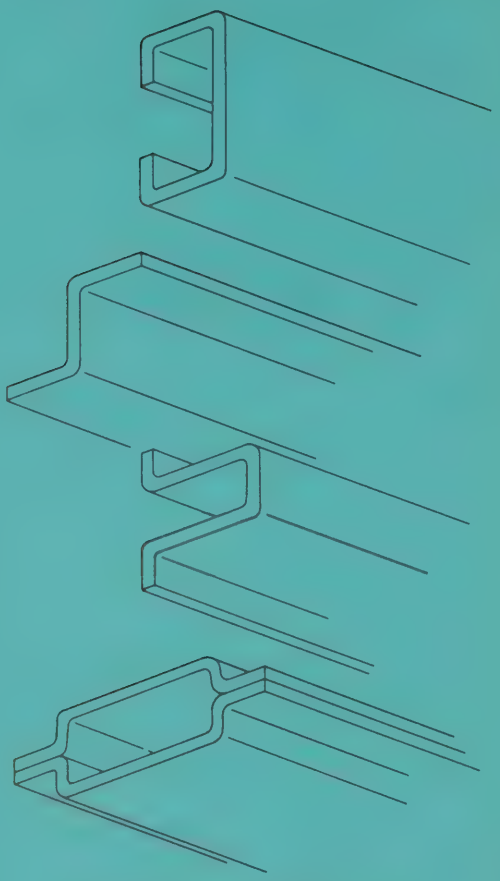
Stainless wire may be hard drawn for high strength or spring temper. It may also be obtained annealed with merely a light final drawing pass for surface finish. Stranded wire and cable are made of stainless steel.

A few small channels and angles are regularly produced in stainless steel. Economics and the nature of the material encourage specially formed sections made of sheet or plate in lieu of standard structural sections. The high strength of stainless usually allows stiffeners, columns, framing, beams, and the like to be made of very thin formed stock.

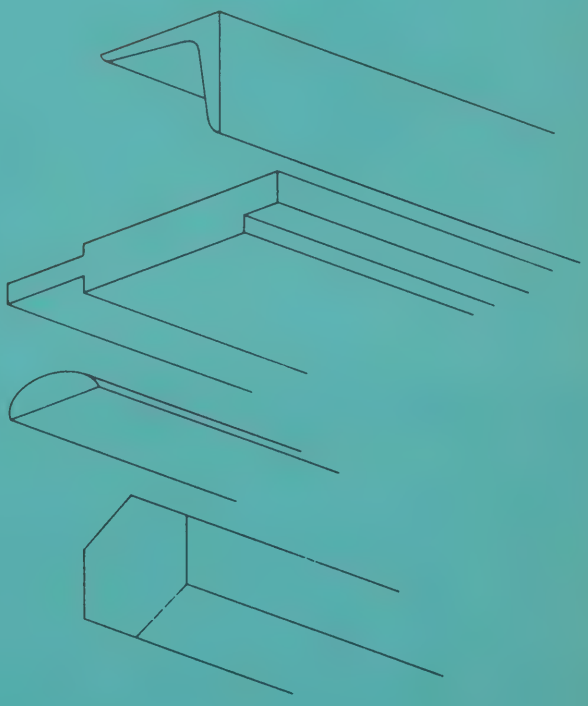
Stainless is drawn into very fine wire to close tolerances for such applications as this magnetic recording wire and special-purpose wire brush.



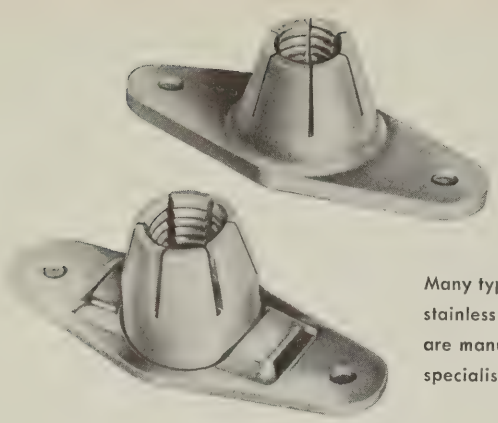
Plates and sheets are available as mill products with stainless clad on one or both sides.



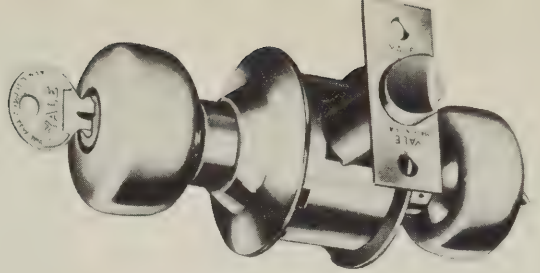
Typical formed structural sections used in high strength stainless design.



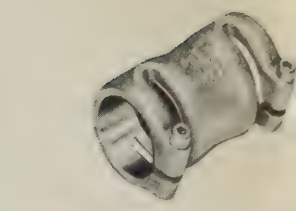
Standard and special rolled or drawn sections are employed less frequently in stainless.

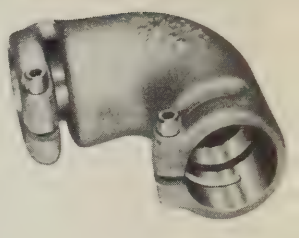


Many types of stainless fasteners are manufactured by specialists in this field.



Stainless lock sets are produced in quantity.





You can eliminate certain shop costs with

If the designer is familiar with the partly processed materials that are available, he can often take advantage of mass production in some supplier's plant and avoid costly production of a few parts with his own facilities. Common items of hardware, for example, can almost always be purchased more advantageously than they can be produced in small lots.

HARDWARE AND FASTENERS. A variety of latches, hinges, and the like are made of stainless. In the instances when the exact item desired cannot be found readily, it is common design practice —but usually less satisfactory—to specify a high nickel-copper alloy or a chromium plated part.

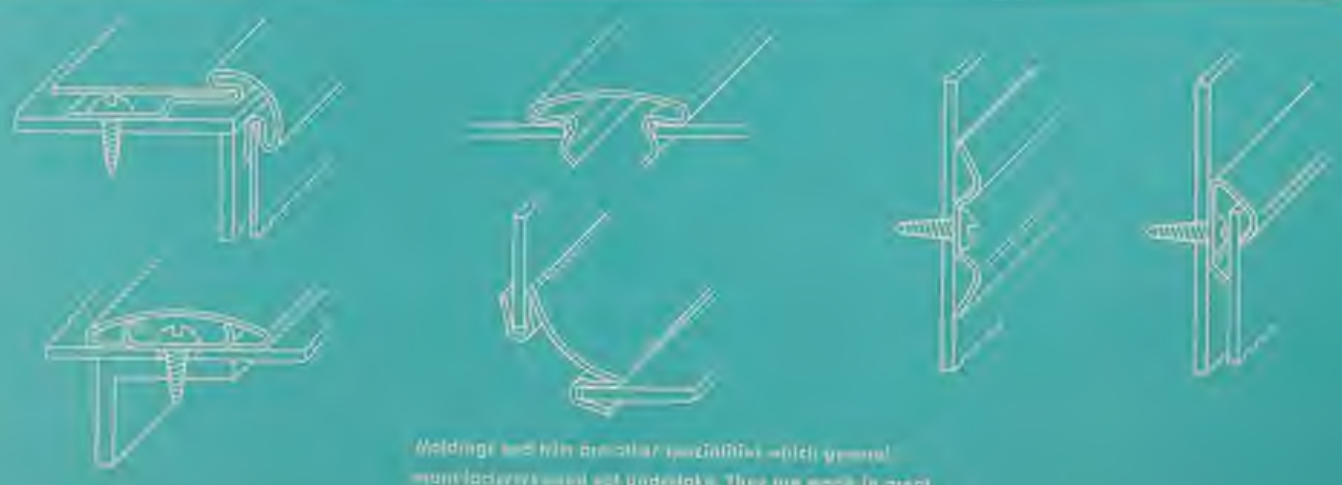
Stainless steel tapping screws for sheet metal are on the market in almost all sizes and shapes. Some, for architectural applications, come with rubber or plastic gasket washers that compress to make a tight seal when they are driven home. Often, stainless steel screws are plated with a thin coat of cadmium that acts as a lubricant during actual thread-tapping. Such stainless hardware is used for assembling plated steel and aluminum exterior wall panels as well as those made of stainless.

Standard nuts and bolts are made of stainless in most sizes. Stainless bolts and nuts for elevated-temperature service may be silver-plated for lubrication.

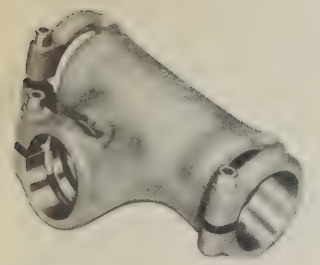
Stainless wood screws are available through some suppliers.

Special nails and drive screws are made of stainless. Roofing nails are furnished with rubber, nylon or lead sealing gaskets already applied.

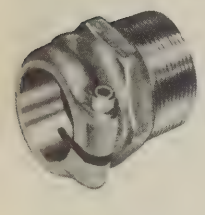
COLD ROLL-FORMED SHAPES. An advantageous way of producing shaped sections of stainless in production quantities is by cold roll forming. Because of its high melting point, stainless can be extruded only with rather elaborate equipment. But the excellent ductility and formability of most stainless grades makes them naturals for roll forming into shapes similar to those extruded in softer metals.



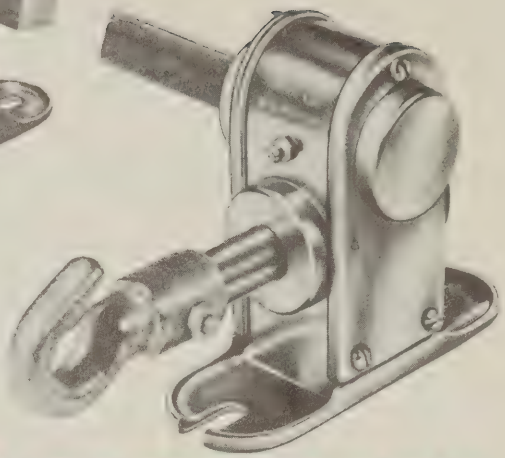
Moldings and trim are other specialties which general manufacturers usually let undertake. They are made in great variety of shapes and provide for various attaching methods.



Many items such as these pieces of stainless awning hardware, which are made with special tooling, are usually best purchased from a specialty manufacturer.



Clamp-on fittings with O-ring gaskets can be purchased in stainless alloys for use with thin-wall stainless steel tubing. Conventional threaded fittings and flared pressure fittings of stainless are, of course, widely distributed.



manufactured units and components

Concerns that specialize in making formed members out of long coiled lengths of strip produce standard shapes for which there is no tooling cost. Some also have accumulated many special roll sets whose cost has been written off on prior orders. These firms publish catalogs of shapes they are prepared to roll. Designers of products that require shaped structural or trim members of stainless should inform themselves of the choices available.

PERFORATED AND EXPANDED METAL. Metal-perforating specialists make two general types of products out of stainless. They make decorative grill stock of relatively thin metal with various patterns of punched-out areas. They also produce industrial, process-plant screening. This is usually of heavier metal. Its purpose is to screen out water, liquors, solvents, etc., and the pattern of perforations is designed to meet specific process conditions. Any type of perforated metal should be a purchased item, because the techniques and equipment for producing it are highly specialized.

Expanded metal has diamond shaped openings formed by stretching a piece of sheet or plate that has been intermittently slit. Expanded stainless steel is produced of fairly heavy stock as well as the thinner gauges. It is often rolled flat after the expanding operation.

FORMED PARTS IN STAINLESS. There are metalworking concerns that specialize in drawing and stamping stainless and other metals. Such organizations, because of their investments in plant equipment capable of doing this work and the unusual skills they possess, can handle what might amount to very elaborate "problem jobs" as routine operations.

Such parts amply justify their cost as outside purchased items when their added complexity results in simplified assembly, elimination of troublesome joints, new performance features for the product, better appearance or similar benefits. The designer will usually have to investigate each individual case to determine which stamped or drawn

A laboratory oven uses expanded metal for shelves—another example of a specialty item designers can use for economy and practicality.

parts should be produced with his normally-available shop facilities and which purchased outside. Unless your facilities include modern, specialized press and die equipment, there will occasionally be difficult pieces that can be produced most satisfactorily, on schedule, and most economically by an outside vendor.

A designer should consider spinning stainless parts that are needed in modest quantities and that have generally dish-shaped, conical or ring-like contours. Spinforming, too, is a specialty, and most pieces produced this way will be purchased items.

It may be worth while to investigate mechanical spinning where quantities are larger and where the stainless part needs to be reduced rather severely in section thickness while being spinformed.

CASTINGS AND FORGINGS In most manufacturing operations, stainless castings and forgings will be purchased from reputable concerns in alloy foundry or forging work. The general shop will usually be equipped for machining and finishing these parts, however,

Stainless castings are poured in quantities as parts of valves, pumps, etc. for corrosive service. Design limitations are the same as those observed for other steel castings. Uniform sections, generous radii, adequate tolerances where shrinkage becomes a problem, ribs for bracing—all the conventional detail requirements apply.

Precision castings of stainless are made by investment molding techniques. With excellent surface finish and tolerances in the range of .005 inch or less, this type of casting frequently eliminates or greatly reduces the need for machining.

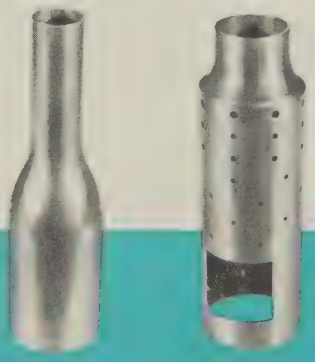
Casting alloys of stainless correspond to similar wrought alloys that have AISI type numbers. Refer to the table of Alloy Castings Institute alloys on page 4. As regards corrosion and heat resistance, the casting alloys perform essentially the same as wrought alloys of the same composition and surface finish.

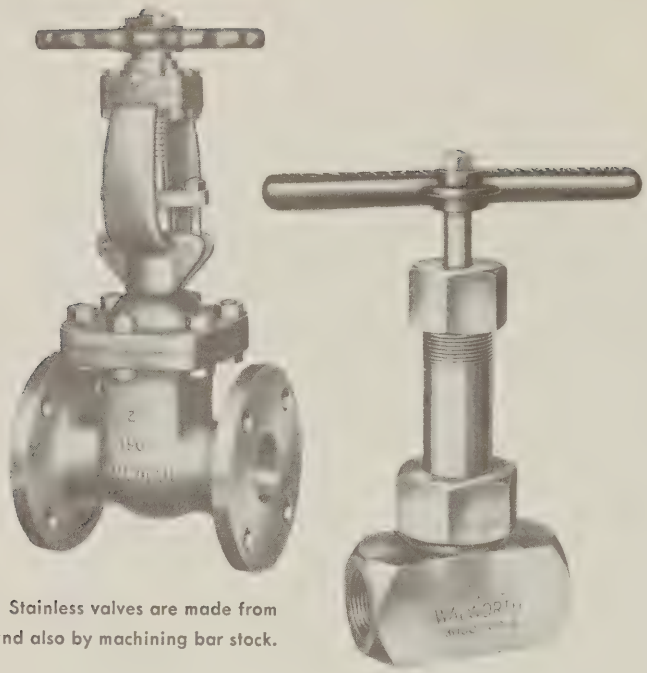
Hot-forged parts can be made in practically all stainless grades. Because of their great workability at room temperatures, the chromium-nickel stainless steels are often cold worked instead of hot-forged. Many forgings made of the chromium stainless types that are hardenable by heat treatment are first machined in their annealed con-

Conventional stainless flatware pieces are forged to achieve "grading"—the tapering of certain sections.

This filter element consists of a sintered stainless disc on a perforated backup plate.

Spun parts made from stainless thin-wall tubing.





Stainless valves are made from castings and also by machining bar stock.

dition. Then, before finish machining or grinding, they are heat treated for high strength, hardness and maximum corrosion resistance.

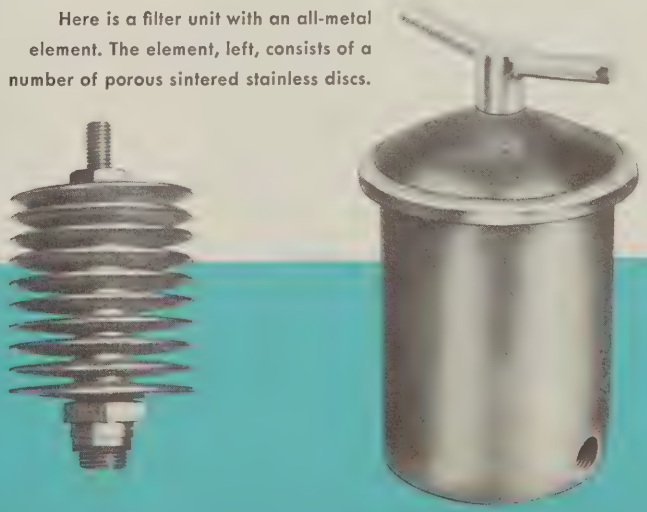
Typical applications for stainless forgings are golf club heads, turbine blading, cutlery and surgical instruments. Parts with mechanical and performance requirements similar to these examples will probably make good forgings in type 410, 416, or 440 A, B or C.

Cold forging or coining is done on the 18-8 types with annealing between steps if the operation is severe.

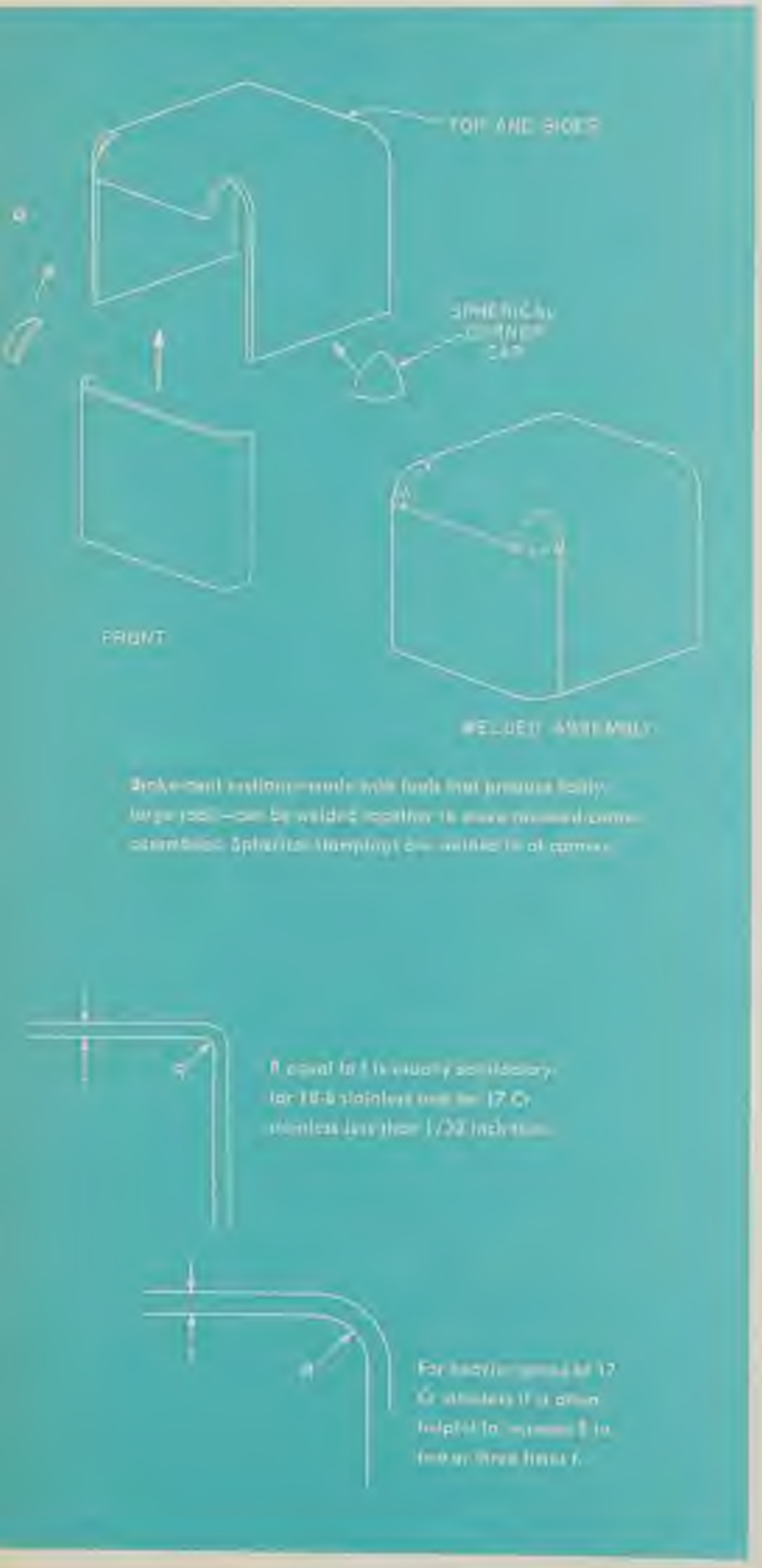
COMPRESSED, SINTERED PARTS Powder metallurgy has been applied to stainless to produce precisely shaped parts, lubricant-impregnated bearings and metal filters. When stainless powder is heated under pressure in a die to make a sintered part, the variables of the process can be controlled to yield the density or porosity desired. Thus, the resulting part is precisely formed dimensionally, and it has whatever proportion of voids the designer requires over a wide range. This quality makes possible solid, corrosion-resisting metal filter discs of stainless steel.

Surgical tools are carefully hardened stainless forgings.

Here is a filter unit with an all-metal element. The element, left, consists of a number of porous sintered stainless discs.



Ways of forming



As a general rule, materials should be treated according to their own peculiarities. A part might be made of plastic, light alloys or painted steel without any change of shape and dimension. But economical operation requires that each material be treated according to its peculiarities. Obviously, you shouldn't treat plastics like light alloys—or stainless like painted steel.

Stainless doesn't impose many special rules, but there are differences between stainless and other widely used metals. When a designer knows these differences, they will usually help him achieve substantial manufacturing savings. Occasionally such savings may even enable him to justify using stainless and adding that feature to his product's good qualities instead of having to be content with a cheaper metal.

The remainder of this book is devoted to a more detailed discussion of processes and techniques used with stainless that have been touched on in the previous pages.

Many stainless steel parts and products are made of sheet, strip or plate, and forming is one of the major shop operations at most plants where stainless is fabricated. The reasoning behind this trend is that stainless steel, because of its good resistance to corrosion and wear, and its higher ultimate strength, is often employed in thinner sections than other metals or non-metallic materials. Formed sheet-metal shapes are more often used than castings. Formed, hollow shapes are more often used than solid metal. Forming lends stiffness and strength without expenditure of extra material or added weight.

Among the principal metal-forming operations are brake bending, roll forming, drawing and stamping, spinning, stretch forming, and tube forming.

BRAKE BENDING is a basic sheet-metal operation. Virtually all sheet-metal shops are equipped with power press brakes, and quantities from one-of-a-kind up to hundreds or even thousands are formed economically.

Brakes make straight-line bends with radii that are controlled by the tools employed. The length of bend that can be made depends, of course, on the dimensions of the brake.

Chromium-nickel stainless steels in the annealed condition can be bent to sharp radii if necessary. In

almost every kind of part, a designer may specify radii equal to metal thickness.

Type 430 stainless is brake formed, but somewhat larger radii are advisable. The recommended inner radius ranges from one to two or three times metal thickness, depending on thickness of stock, angle of bend, finish requirements, and orientation of bend with respect to the original rolling direction of the metal. A sharp bend—especially one whose axis parallels the rolling direction—will tend to show an "open" or roughened texture along its outside edges. There are several alternatives—polishing the roughness—using a larger radius—adopting special shop techniques like preheating the metal or arranging for proper orientation relative to the rolling direction.

As a general rule, allow a radius of about one metal thickness for Type 430 stock of .032 inch and thinner. Increase this to two or three thicknesses for heavier pieces.

ROLL FORMING is a high production process. Formed sections are usually made from strip stainless in continuous lengths that can be cut as required. Sometimes, the ends of a part are punched, pierced, or otherwise processed first. Then, ready-to-cut or cut-to-length pieces are run through forming rolls.

An investment in rolls and setting up the rolling stands to produce a new section can be either modest or prohibitive—depending on the quantity of material to be roll formed.

The designer of a mass-produced product can often use a roll-formed stainless section that he designs expressly for that product. Stainless automative window trim, for example, is usually roll-formed of Type 430 stainless, and new tooling is amply justified when desired for model changes.

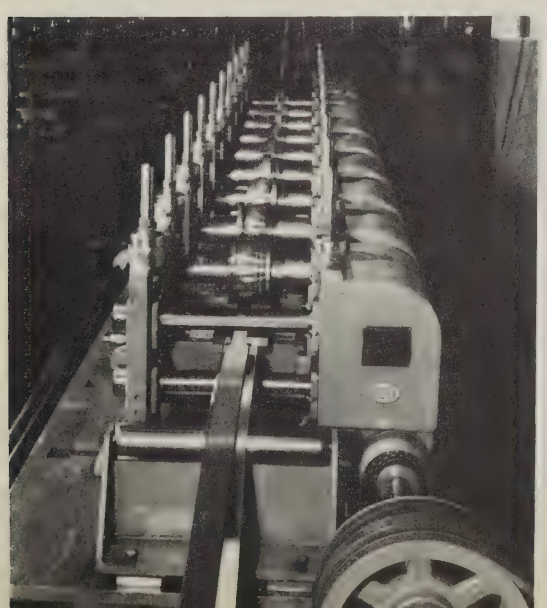
On the other hand, a designer with a more modest requirement for formed shapes can usually select a stock section that will serve his purpose. Thousands of sections for trim, mouldings, edging, architectural framing, panels, and special purposes have been designed and fabricated. Roll forming specialists keep either a stock on hand or have tooling available to produce many of these sections. Their published catalogs are available on request.

Any designer with occasional use for formed sections of stainless or other metals can profit by having data on stock roll-formed sections in his reference library.

DRAWING AND STAMPING of stainless are much like the same operations with other metals. Type 430 behaves somewhat the same as mild steel, although it is stronger and requires heavier die forces. The 18-8 stainless types have a tremendous capacity for stretching and deforming. Like copper or brass, they work-harden as they stretch, and may have to be annealed between progressive operations if extremely severe forming is necessary. However, both the annealed and work-hardened strengths of stainless are several times those of copper and brass. The similarity to these metals may be useful for designing shapes, but shop equipment for working stainless will have to be considerably more powerful.

When a part is so shallow that it might be made by stamping rather than by drawing, there are two general precautions that will keep a design from giving trouble in production.

First, dimpling or flaring of small holes should



Roll forming of stainless is an economical way to produce large quantities or long sections of lightweight, strong structural members as well as decorative and protective moldings and trim.

This simple drawn stainless mixing bowl typifies the kind of forming that is done economically. The same general shape is used in producing component parts for a variety of products.

be approached cautiously. It is important that the edges of the hole be free of burrs or nicks. To do this kind of forming without tearing the metal requires that the material flow inward from all directions, and that a relatively large area of material be deformed by force applied in a very concentrated way. Thus, a cup that might be drawn easily from a small blank cannot be formed at all in the middle of a large sheet.

The second general precaution concerns wrinkling—the problem that arises at corners and flanges, for example, where metal must be shortened along one dimension and still remain flat and smooth. Stainless steel—especially in the 18-8 grades—can be stretched, but "shrinking" it is a far harder job.

The sketches below show how notches, cutouts and narrow flanges can be employed to minimize this difficulty. There are forming techniques employing multiple dies, hydraulic cushions, etc., that overcome the tendency to wrinkle. Parts made with more elaborate equipment may be more costly, however.

The depth of cup that can be formed readily in a single draw with Type 430 stainless is about one-fourth of cup diameter. This depth is about three-fourths of cup diameter for an 18-8 stainless like Type 302. Expressed as percentage reduction:

$$R = 100\frac{D}{D-d}$$

where D is blank diameter and d is cup diameter, these approximations correspond to about 30 per cent for Type 430 and 50 per cent for Type 302.

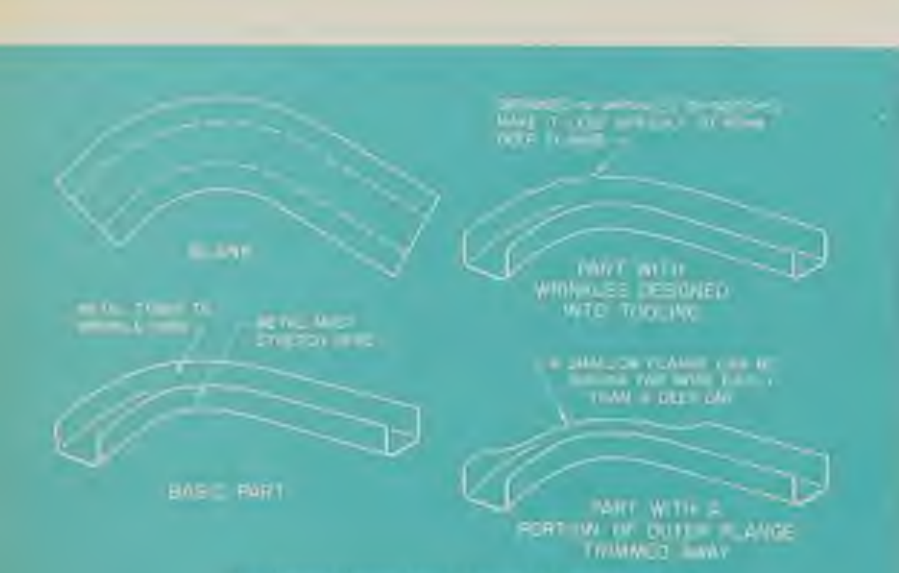
Minimum radii of 4 to 16 times metal thickness at the base of a cup and at the base of a flange, if any, will help prevent difficulties. When the part is not round, but box-shaped, ample corner radii in the plan view—say 10 per cent of box width—are helpful.

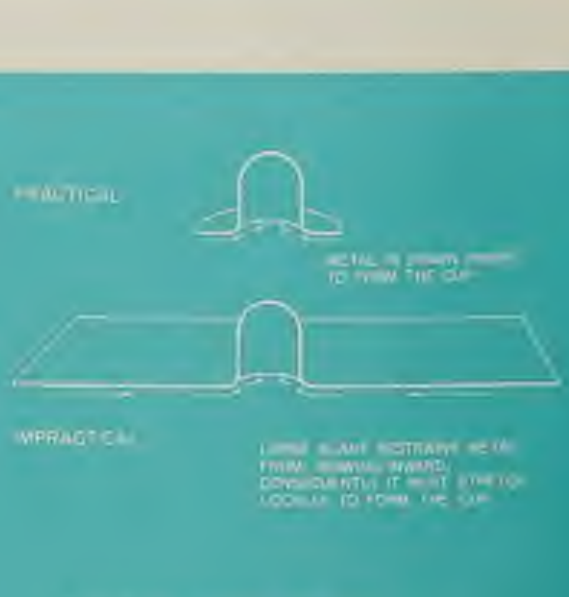
SPINNING is a lathe forming operation that offers many advantages for producing sheet stainless parts with symmetry about an axis of rotation. Spinning has gained a reputation for economy on short runs or one-of-a-kind jobs because the chuck or form over which the metal is worked can be lathe-turned out of wood. It can thus be a great deal cheaper than press tooling. However, stainless parts are also spin-formed in fairly substantial production runs, too. The process meets some kinds of design requirements better than any alternative method.

Consider spinning for stainless rings, cones and formed cylinders, as well as for the common lid shapes. Generally, the closer the blank resembles the part, the easier the spinning job will be. A rolled up and welded cone, cylinder, or band may be used as a blank as well as a flat disc. Commercial thin-wall stainless tubing, which is available in diameters up to 36 inches may be cut into lengths for spinning blanks.

The cost of spun parts will be lower if ample tolerances—in the order of ±0.016 inch or more—can be accepted. Generous radii also help keep costs in line. For stainless, a good working minimum radius is five times blank thickness, though sharp corners can be formed if needed. The shape of a part may affect costs if it involves an undercut that prevents easy removal of a simple, solid chuck.

The finish of the original stainless blank is usually





destroyed during spinning, and then the spinner refinishes the part according to design specifications as a final operation on the spinning lathe.

TUBE FORMING covers both bending tubular pieces and swaging or upsetting them to change their diameters or thickness in certain portions.

Bent stainless tubing has many applications where costs can be kept reasonable by observing a few production limitations. The chief thing is to specify large enough bending radii, if possible, so that the piece can be formed with simple tooling. The table at right may be a helpful guide, but it should not be used without further checking with the shop that will actually do the work if there is any doubt about the design you have in mind.

Make each individual bend continuous, of constant radius, and in one plane. Keep the bent portions away from each other by several diameters, if possible.

Swaging, flanging, beading and tapering are some of the cold working operations that can be performed on the ends of stainless tubing. Wall thickness can be made thinner, controlled to exact dimensions, or made heavier, within limits. Such operations all require special tooling, but can give the designer attractive functional or decorative features where quantities are sufficient to justify the cost of tools.

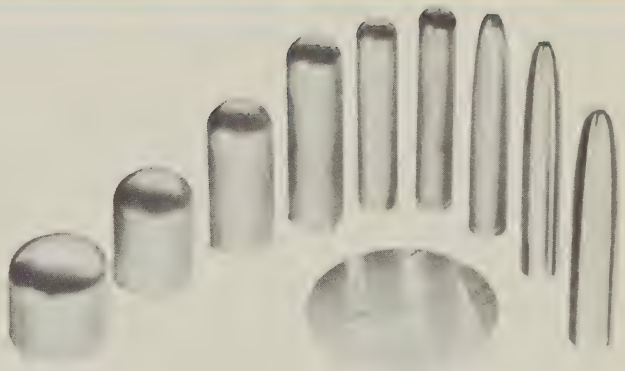
Flattened and punched or drilled ends can always be used if the simplest possible mechanical joint is desired. Abrasive sawing is a good way to prepare tube ends for welded joints. Flared tube fittings are used for pressure lines.

SUGGESTED MINIMUM* BEND RADII FOR STAINLESS TUBING

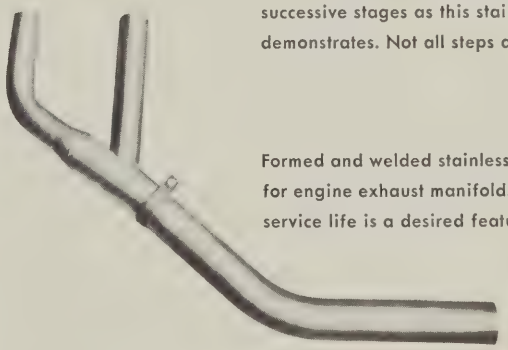
(In Inches—Measured to Centerline)

Outside Diameter of Tube, Inches	Wall Thickness, Inch					
	.031	.037	.050	.062	.078	.109
⅜	1¼	1⅛	*	*	*	*
½	*	1½	1⅜	1¼	*	*
¾	*	2¼	2⅛	2	2	*
1	*	*	3	3	2¾	2½
1½	*	*	4¼	4⅛	4¼	4
2	*	*	6⅛	6	6	6
3	*	*	*	9	9	9

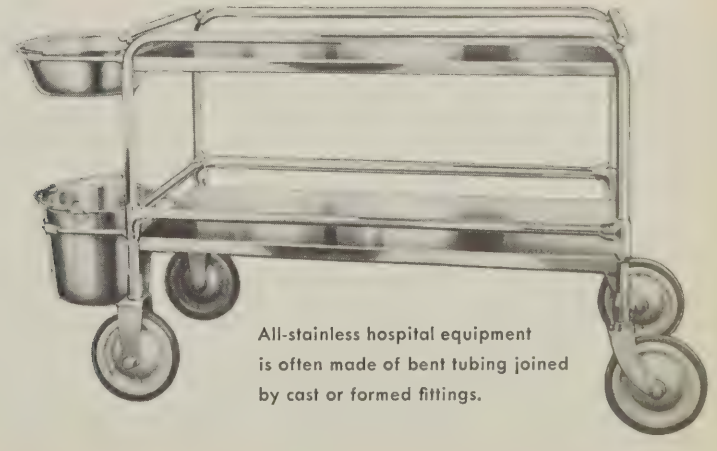
*Note: Above radii are for 90° maximum bends without a mandrel inside the tube. Sharper bends can be made with a mandrel. Larger radii are recommended for 180° bends, and several times larger radii are required for continuous rolling.



Extremely deep drawing can be done by successive stages as this stainless pen cap demonstrates. Not all steps are shown here.



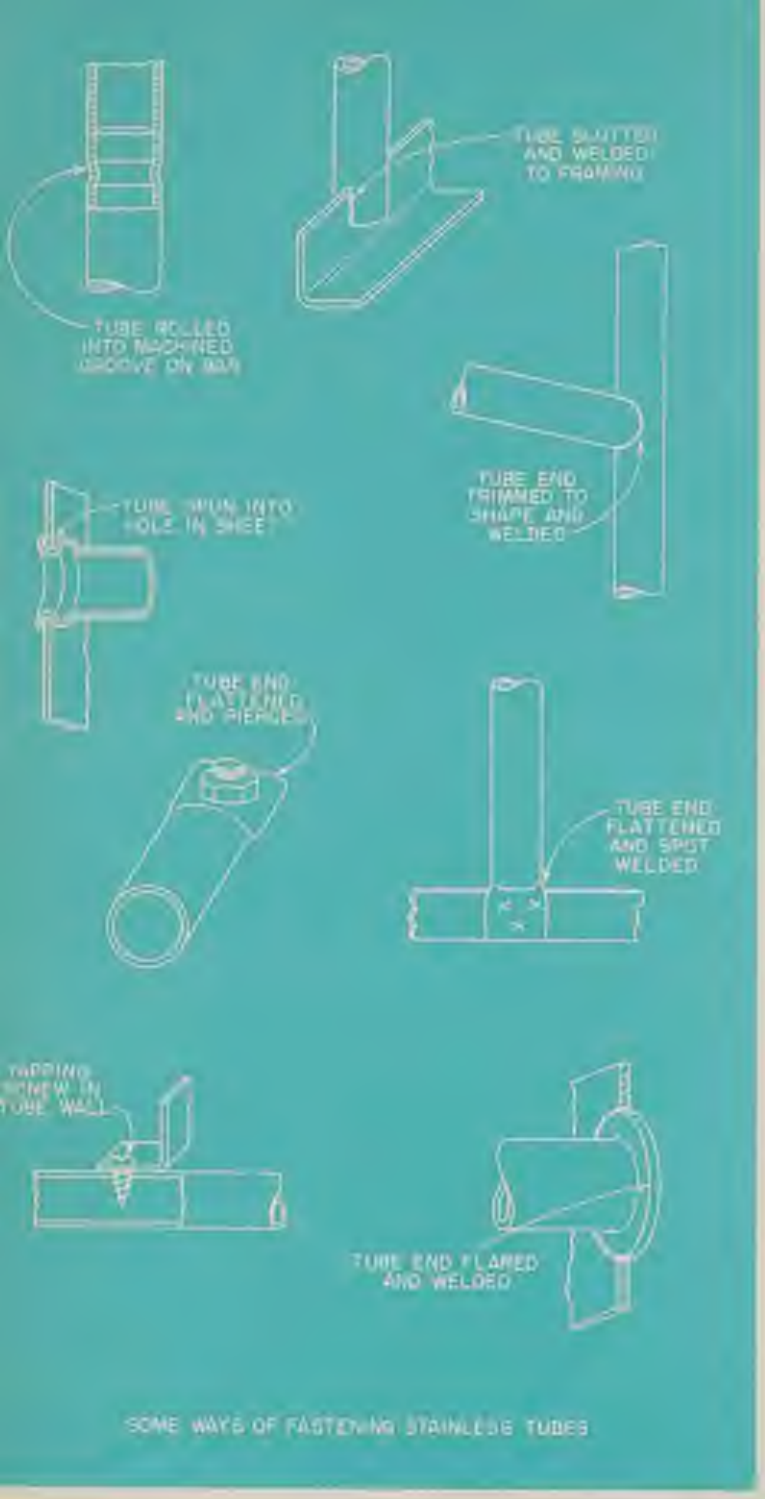
Formed and welded stainless tubes are used for engine exhaust manifolds wherever long service life is a desired feature.



All-stainless hospital equipment is often made of bent tubing joined by cast or formed fittings.

$\frac{\pi d^2}{4}$ + side tapers = $\frac{\pi D^2}{4}$

Percentage reduction, $100\frac{D-d}{D}$, in a single draw (can be about 50% for Type 302 or 30% for Type 430 stainless. Draws of far greater severity are regularly made, but they sometimes require special tooling or other precautions.


TUBE SLOTTED AND WELDED TO FRAMING
TUBE ROLLED INTO MACHINED GROOVE ON BAR
TUBE END TRIMMED TO SHAPE AND WELDED
TUBE SPUN INTO HOLE IN SHEET
TUBE END FLATTENED AND PIERCED
TUBE END FLATTENED AND SPOT WELDED
TUBE END FLARED AND WELDED

SOME WAYS OF FASTENING STAINLESS TUBES

Ways of joining

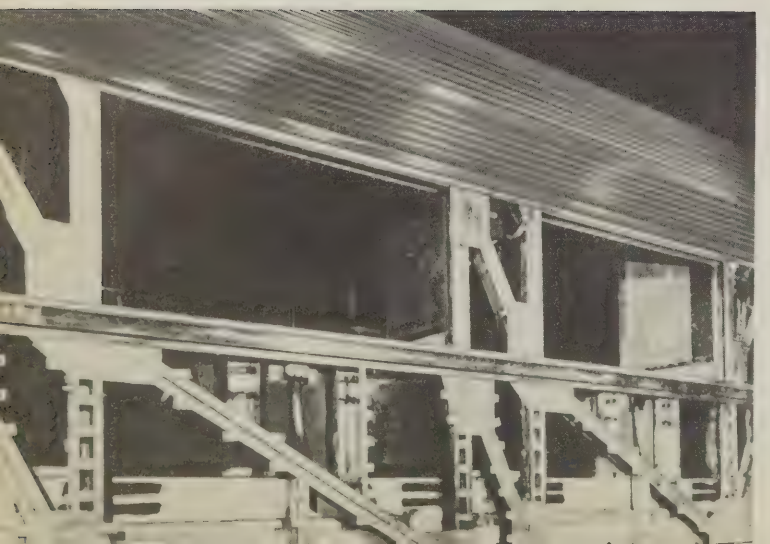
When two stainless steel pieces are to go together permanently, welding is usually the best way to make the joint. Sometimes tabs and lock seams are used in joints that allow some freedom of movement. Screws and bolts are an obvious choice where disassembly may be necessary. Sometimes threaded fasteners offer the cheapest, best way of assembling a product, even if an essentially permanent joint is desired. Soldered, silver soldered or brazed joints find some applications. Also, stainless steel is sometimes bonded to plastics, aluminum, and other materials by being cast or molded into the part as an insert.

WELDED JOINTS in stainless steel can be made by any of the common processes. Ordinary metal arc fusion welds are easy to make and satisfactory for many jobs. Inert gas-shielded arc welding produces a smoother bead with less spatter. Electric flash welding is good for butt joints in bars and tubes, and the various stud-welding systems all work well with stainless. Resistance spot and seam welding offer speed, economy and reliability—especially for high-strength, light-weight structures.

Fusion weld beads are often ground smooth for sanitary or appearance reasons. Well-made automatically controlled inert-gas shielded arc welds are often smooth enough for use after electro-polishing only. All the chromium-nickel stainless steels are amply ductile to withstand the thermal strains of welding. The weld bead is also soft, tough and ductile. Acetylene welding, if not properly done, may cause carburization and result in welds of poor strength and low corrosion resistance.

The hardenable stainless types can be welded but may need to be handled with special procedures to keep them from cracking. Hardenable types, in which carbon exceeds .20%, are preheated to 500°F, welded at this temperature and annealed after welding. If hardening and tempering follow immediately after welding, annealing can be eliminated.

Chromium stainless Type 430 is welded successfully in the manufacture of many products. The heat of welding does cause metallurgical changes to



The original Burlington Zephyr pioneered railroad applications of thin-section, spot-welded, high-strength stainless construction. An inspection disassembly, left, showed no deterioration after 13 years—unheard-of performance for conventional construction. Spot welding is the key to this type of design.

occur that may make for brittleness and loss of corrosion resistance at the welds. Remedies include post-weld annealing and the use of Type 430T, which was developed especially for this purpose. Type 446 is weldable and the welds are ductile at the elevated temperatures for which Type 446 is used.

Generally, none of the free-machining types should be joined by welding.

Corrosion resistance may be affected by the heat of welding. The chromium-nickel stainless steels undergo a change known as carbide precipitation when they remain in their "sensitizing" temperature range—800F to 1600F for most types—for any length of time. This change takes away some of the stainless steel's corrosion resistance. After carbide precipitation has taken place, full resistance can be restored again by annealing the metal above 1800F then cooling it rapidly.

Whenever a weld is made in an unstabilized chromium-nickel stainless, some of the metal at or near the weld will be heated for a short time in the sensitizing temperature range. If the time spent at these temperatures is less than a minute or so, there is no danger of trouble from corrosion in ordinary applications. Thus, welded Type 302 is used in many household and outdoor exposure situations without being annealed.

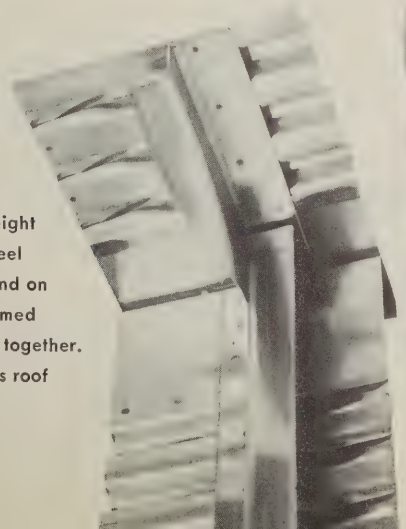
In making industrial equipment with strict corrosion resistance requirements and, perhaps containing heavier stainless plate which would require multipass welding with repeated heat applications, Type 304 or Type 304L stainless might be used instead of Type 302. These alloys are held to lower maximum carbon contents than Type 302, and their compositions tend to limit carbide precipitation. It is possible to get even more protection against effects of welding heat by using one of the "stabilized" grades, Type 347 or Type 321. These alloys are designed for actual service at temperatures above 800F, and they will not be harmed by welding heat.

The nature of welded products made of stainless usually points toward making them with butt joints. A butt joint utilizes the metal most efficiently from a strength or vibration fatigue resistance standpoint, and it is easiest to grind smooth and polish. Stainless sheets and strip as thin as .032 can be butt welded using a tungsten electrode and an inert gas shielded arc. Thinner metal than this is usually resistance welded with some form of lap joint.

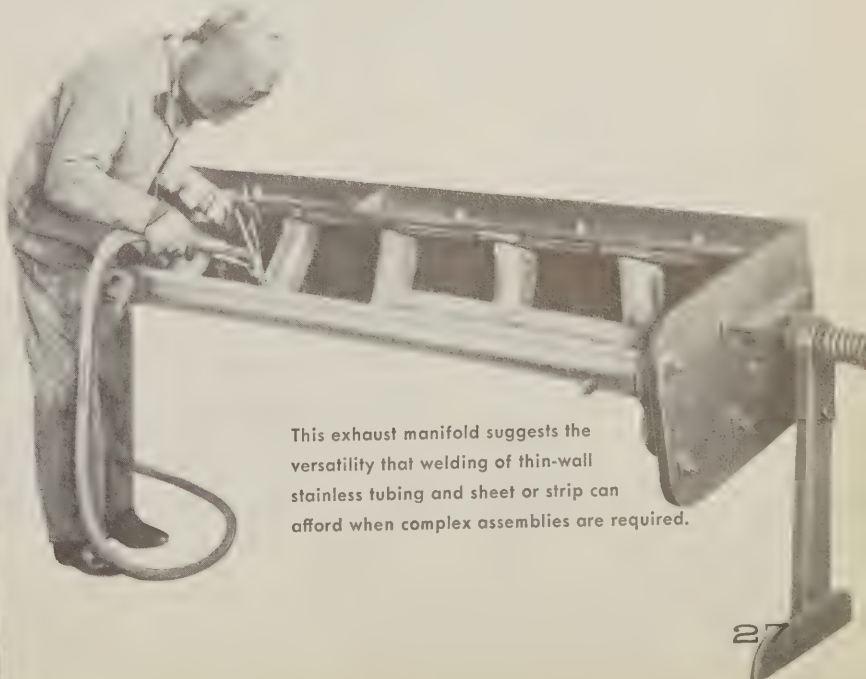
Spot welding serves very well for joining thin stainless pieces. It is also used for heavier work where designs require strong, reliable structural joints but not necessarily the smoothness and continuous surface obtainable by grinding and polishing a butt weld.

Spot welds cost less than rivets or threaded fasteners in most cases. The designer can use spot welds very much as rivets have been used in the past—to attach handles, brackets, hinges, tabs, braces, and the like.

Seam welding makes sound, leakproof vessels and tanks. Many hundreds of thousands of refrigerator heat-exchangers have been made this way. It is difficult to make a seam weld, however, without a narrow crevice that would be hard to clean. This can sometimes be avoided by a "mash" welding technique. If the vessel will be used for foods, pastes, etc., uncleanable crevices should be avoided in design. It is possible of course, to spot weld such a vessel, then to fill the joint with solder to make a smooth, cleanable interior.



High-strength, lightweight designs of stainless steel highway trailers depend on skillful use of thin formed members spot-welded together. This photograph shows roof and wall construction in sample section.



This exhaust manifold suggests the versatility that welding of thin-wall stainless tubing and sheet or strip can afford when complex assemblies are required.

SCREWS, BOLTS AND RIVETS for fastening stainless steel should all be stainless. Even where a stainless part is joined to another material, the fastener should be stainless.

When fasteners will be concealed, experience has shown that ordinary steel fasteners raise the possibility of rust streaking on the visible stainless. This is a result of condensed moisture that drips from a corroded fastener. To prevent any possibility of streaking from this cause, use stainless fasteners in concealed places, too.

Standard sizes and types of screws are made of stainless. The various drive screws and tapping screws for sheet metal work are made in a wide variety of standard and special-purpose modifications. For example, self-tapping screws for applying stainless exterior wall panels are made of work-hardened stainless which is then cadmium plated. The plating, of course, serves no protective purpose, but it acts as a lubricant for the severe thread tapping operation involved when the screw is used.

Many standard nuts and bolts are available in stainless. If special threaded parts are required, they can be turned out of the free-machining stainless that has the same general characteristics as the other metal involved.

Rivets are available in the 18-8 chromium-nickel compositions, and also in Type 410 and Type 430 stainless. Up to $\frac{3}{16}$-inch diameter, stainless rivets may be driven cold. Larger sizes are heated with very careful control of temperatures. Squeeze riveting is usually preferable to hammering.

It is better to call for drilled rivet holes than punched holes, but punched holes are acceptable if they are reamed through both mating parts.

TABS, BENDS AND LOCK SEAMS fall into two general categories. In one are joints made by high-production machines, and in the other are folded roofing seams of the designs that have been made by sheet-metal craftsmen for generations. In terms of product design, the machine-made joints concern us most.

There are many good reasons for employing tabs that fit into slots, flat spring latches and simple bayonet joints on stainless products. For one thing, these devices save money if they are designed so that they can be formed by the same tools that do other essential operations. As has been stressed, most stainless is used as relatively thin, polished sheet metal. Thus, almost any part can have an appendage that is a natural spring, and there's no paint to chip or scrape. Very often a flat stainless spring catch or tab is spot welded to a larger member.

Another reason for joints that are "quick opening" in contrast to conventional screws, for example, is for access to products that should be cleaned inside or which have replaceable parts inside. The designer usually has a choice of sealing a case or covering permanently or allowing disassembly for occasional cleaning. In the latter case, disassembly should be easy, and spring clips then become a product feature as well as a cost-saver.

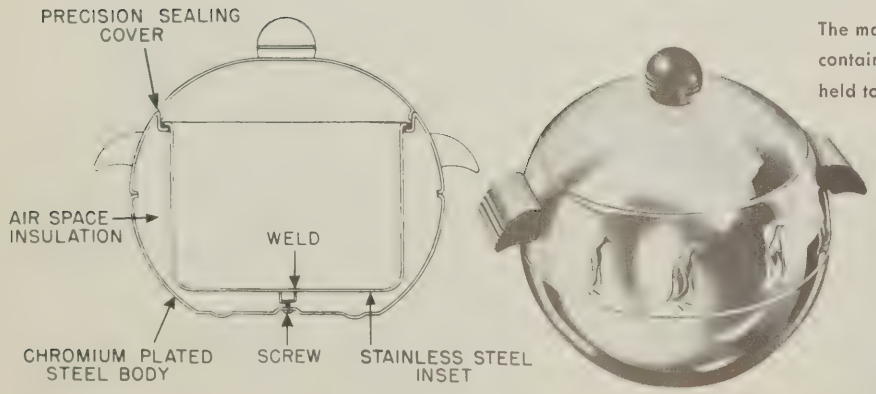
The accompanying examples show typical arrangements, but each new problem will require its own design solution.

Lock seams may be formed by appropriate dies for punch press work. Roll forming tools have been developed to make lock seams on tubular shapes and other long members.

The sharp 180-degree bend required by lock seaming suggests that the extremely ductile chromium-nickel stainless types will assure the most trouble-free production, although Type 430 has also been widely used with this kind of seam.

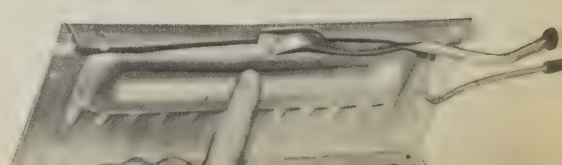
SOLDERING AND BRAZING both have a place in joining stainless, but they have limitations.

Solder should never be used to make a mechanical joint on stainless, because its strength and



The major parts of this plated ice or hot food container, which has a stainless liner, are held together by a single screw at the bottom.

Brazing joins tubes to a stainless refrigerator evaporator section.



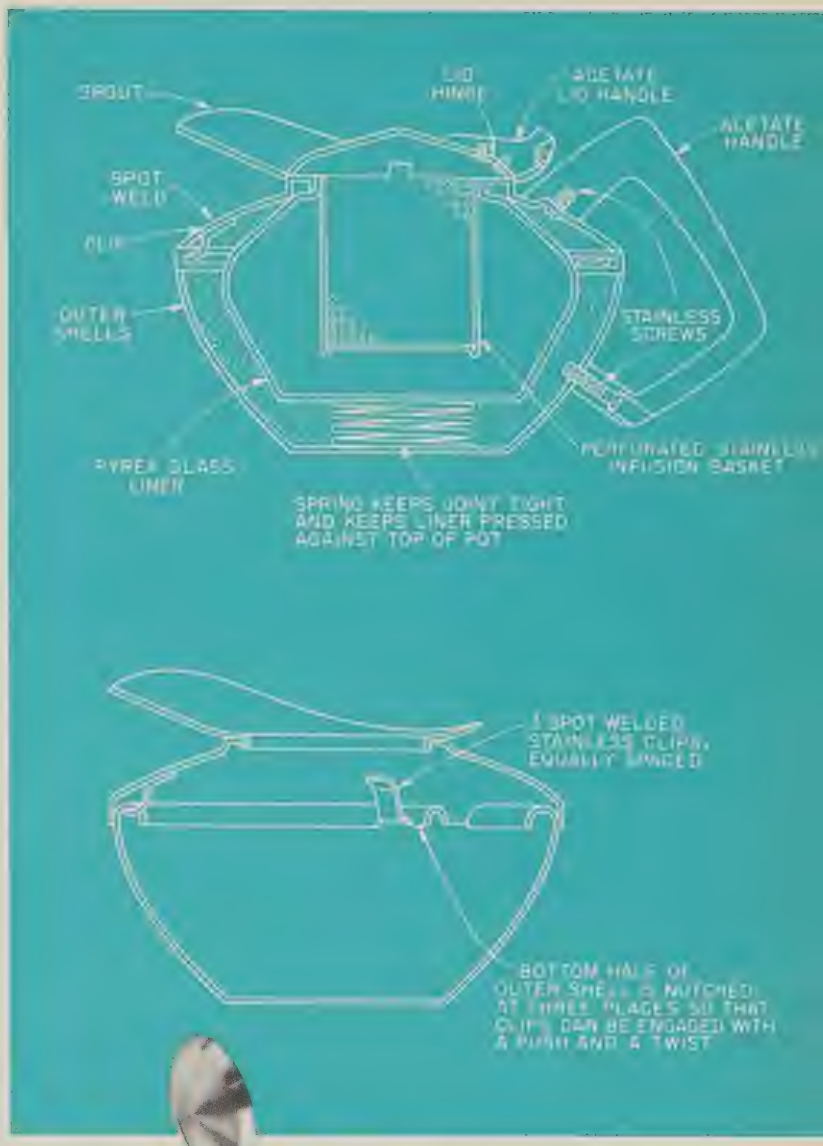
stiffness are so much less than the surrounding metal. This almost inevitably leads to cracking at the joint. However, solder can serve very well as a sealer along a lock-seamed, spot welded, or riveted joint. For best color match, specify a high-tin content solder. Flux must be removed completely after soldering.

Brazing is frequently employed to join stainless to other metals. Brazed joints, for example, are commonly used in refrigeration tubing where several metals are involved. Stainless parts can be brazed together, too, but welding is usually a better choice in this case.

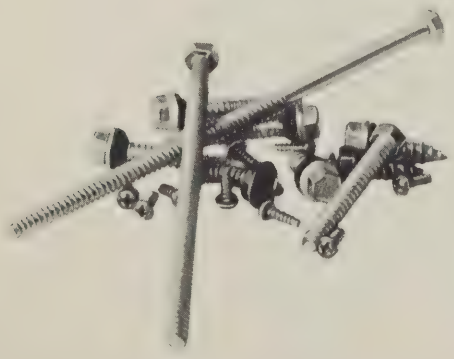
The temperatures at which brazing is done fall within the sensitizing range in which the chromium-nickel stainless steels undergo carbide precipitation. This may not introduce any problem if the brazing operation is done rapidly. A low-carbon stainless steel like Type 304 may be used to limit carbide precipitation—or in some cases even a stabilized grade like Type 347 or Type 321. Whether brazing will precipitate carbides and whether the corrosion resistance of the stainless steel will then be reduced to a critical point in terms of service requirements should be investigated before brazing is specified.

STAINLESS AS AN INSERT in a plastics molding or in a die casting of zinc or aluminum alloy can serve as a pivot, bearing, fastener, latch, striking surface, spring, nameplate or as a purely decorative element. Sometimes the stainless "insert" can be designed to surround a large part of the exterior of a casting or molding so that its working surface will be smooth and hard.

The same general rules apply to using stainless inserts as for other metals. Provide means for locating each insert in the die and for anchoring it positively in the cast or molded part. Make inserts as easy to handle as practicable. If stainless steel inserts are to be screw-machine products, one of the free machining alloys should be chosen.

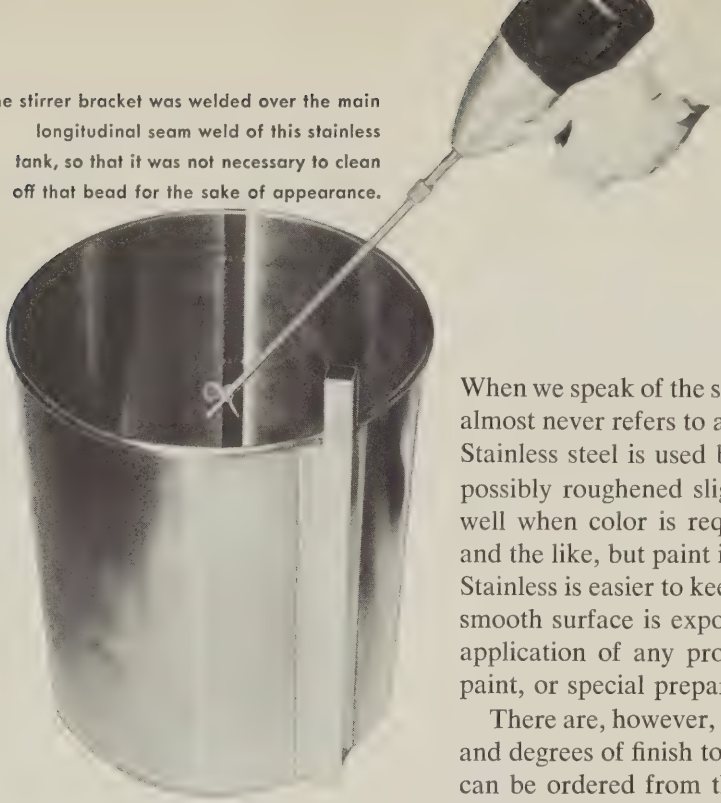

SPOUT
LID HINGE
ACETATE LID HANDLE
ACETATE HANDLE
SPOT WELD
CLIP
OUTER SHELLS
STAINLESS SCREWS
PYREX GLASS LINER
PERFORATED STAINLESS INFUSION BASKET
SPRING KEEPS JOINT TIGHT AND KEEPS LINER PRESSED AGAINST TOP OF POT
3 SPOT WELDED STAINLESS CLIPS, EQUALLY SPACED
BOTTOM HALF OF OUTER SHELL IS NOTCHED AT THREE PLACES SO THAT CLIPS CAN BE ENGAGED WITH A PUSH AND A TWIST

This fiberglass-insulated stainless teamaker is held together by clips that engage the slotted rim.



A typical assortment of stainless sheet-metal screws.

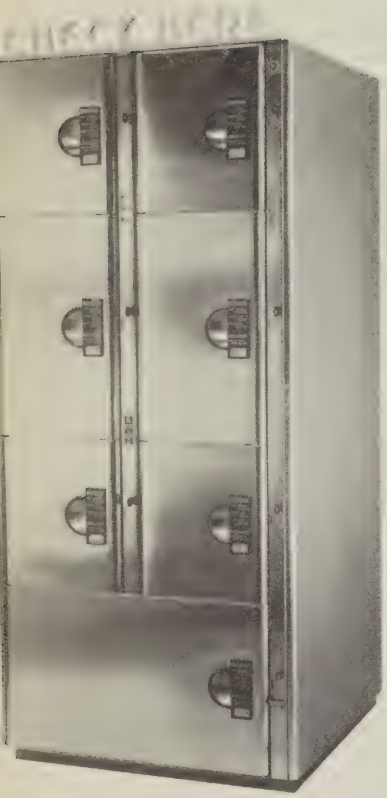
The stirrer bracket was welded over the main longitudinal seam weld of this stainless tank, so that it was not necessary to clean off that bead for the sake of appearance.



Ways of

When we speak of the surface finish of stainless, this almost never refers to an added coating of any sort. Stainless steel is used bare. With a clean surface—possibly roughened slightly—the metal takes paint well when color is required for signs, nameplates and the like, but paint is not applied for protection. Stainless is easier to keep bright and clean if its own smooth surface is exposed than it can be made by application of any protective oil, grease, lacquer, paint, or special preparation.

There are, however, a number of surface textures and degrees of finish to choose from. Stainless steel can be ordered from the mill with a range of finishes, and other treatments can be applied.



Checking lockers—finished with the same treatment as many stainless architectural components—have a uniform "grain" produced by abrasive polishing.

MILL FINISHES are specified differently for stainless sheets than for strip (less than 24 inches wide). The standard sheet finishes may be produced by cold rolling or by polishing with abrasives. The polished surfaces can usually be specified for one or both sides of a sheet.

No. 1 sheet finish is annealed and pickled. After being softened by annealing, the metal has been pickled in acid to make it clean and bright. The surface is frosty, but not usually uniform enough

Examining a sheet of stainless on a polishing machine at the steel mill.

The reflection patterns at right show how several mill finishes compare in luster and brilliance. Illustrated are, left to right, No. 1, No. 2B, No. 4 and No. 7 sheet finishes.

finishing stainless surfaces

for use in a product. If a part will be annealed again or if its surface will be severely marred in the course of its manufacture, the No. 1 finish is a good starting point. Then, after fabricating work is done, the part is shop finished all over.

No. 2D is a dull finish on cold-rolled, annealed sheet. The surface holds lubricants well and the high ductility of the metal makes it good for draw press work.

No. 2B sheet finish is produced by bright rolling after annealing and pickling. This surface is more reflective than many of the polished textures obtained with abrasives, but is not as reliably uniform. It is an excellent base for abrasive polishing or buffing in the shop.

No. 4 sheet finish is the standard polished surface. It has a visible "grain" with a direction established by the motion of the wheel or belt used for abrasive polishing.

No. 6 sheet finish has a soft, lustrous texture imparted by tampico brushing a sheet that has already been No. 4 polished. This process yields a low-reflectivity surface with uniformity and quality that will bear close inspection. It can, however, be marred by repeated rubbing in service.

No. 7 sheet finish is polished with fine abrasives to approach mirror fineness.

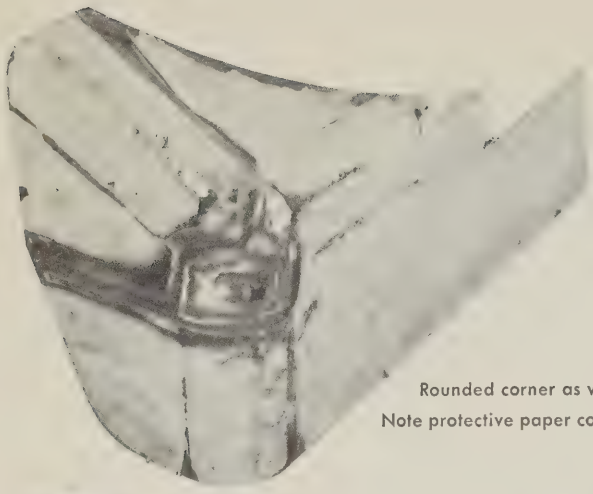
No. 8 sheet finish is a mirror polish that is even smoother and more nearly perfect than No. 7. It is difficult and expensive to produce and is not available except on special order.

Strip stainless, because of its narrower width, is processed in the mill on different types of equipment. Only two strip finishes are designated as standard, although strip stock can always be ordered cut to lengths and supplied with regular sheet finishes.

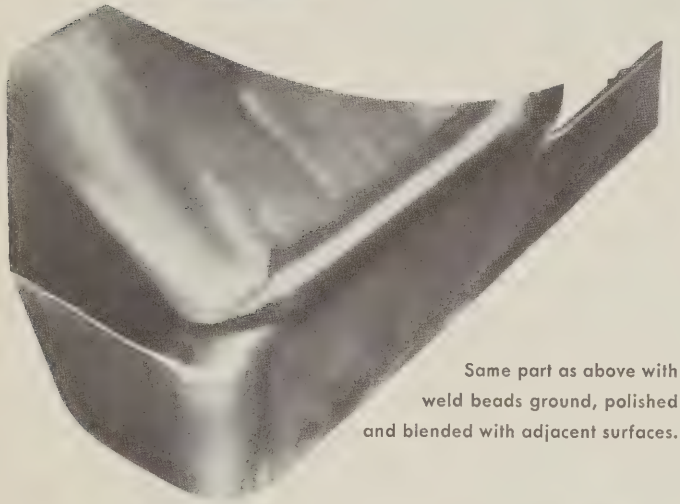
No. 1 strip finish identifies cold rolled material that has then been annealed and pickled. The surface is frosty but not usually uniform enough to warrant using the material in a product.

No. 2 strip finish is about the equivalent of No. 2B sheet finish. It is bright cold rolled.

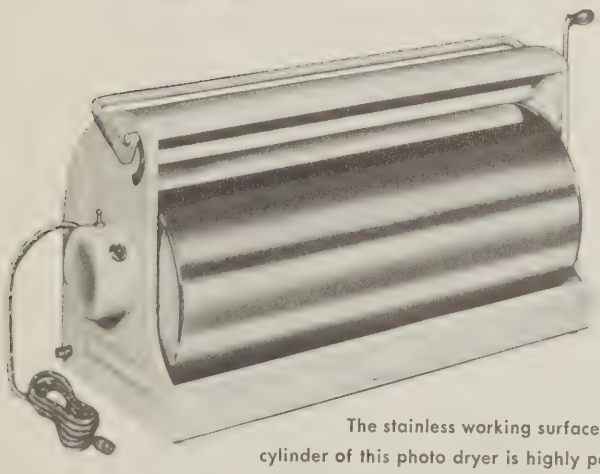
Bars, rods, tubing and pipe are supplied with various pickled, drawn, machined or polished finishes. Stainless tubular products are available with inside surfaces polished for food and process industry equipment. Standard finishes are No. 80, 120, and 180,—corresponding to the abrasive grits used in grinding. Finish R is mirror finish made



Rounded corner as welded.
Note protective paper covering.



Same part as above with
weld beads ground, polished
and blended with adjacent surfaces.



The stainless working surface on the
cylinder of this photo dryer is highly polished
after the weld bead has been ground off.

Weld beads are ground smooth, then
polished where cleanliness is essential.
Note the smoothly rounded corners.

with rouge. These finishes can be applied to either or both sides, as required.

SHOP FINISHING will be required if mill-finished stainless stock is not used—or if a portion of the original mill finish is marred in the process of making the product.

It will help simplify the entire purchasing and manufacturing operation if a clear decision is made at the design stage as to which stainless surfaces are polished and when.

Some products with large areas relatively unaffected by shop operations can be made most economically of mill-finished sheets. In this case, steps should be taken to minimize the damage to which the surface will be subjected. Also, provision for restoring a few small marred areas and blending them (or contrasting them) with adjacent areas should be considered.

On the other hand, stainless sheets for a product that will involve considerable bending, drawing, welding and other surface-marring operations, should not be purchased with a highly mill-finished surface that will need to be done over entirely anyway. In this case, the usual choice is a No. 2D sheet finish which works well in most forming operations because it holds the lubricants used.

There are a number of ways to protect the surfaces of finished stainless in the shop. One is to keep everything clean and to be very careful. Paper is sometimes pasted on surfaces, and special spray-on preparations such as strippable plastic films and surface-protecting lubricants can be applied.

Welding, however, will make obvious marks. Grinding or chipping the weld bead off and polishing will usually yield a fair appearance match with a No. 4 sheet finish. To match the weld beyond detection, it may be necessary to go over the entire surface lightly to establish a new abrasive "grain."

As the arts of making things are perfected, craftsmanship gains a certain recognition and acceptance. In woodworking, for example, joints are often admired for their beauty instead of being concealed or masked. This same trend has gained momentum with stainless. Where food cleanliness is not a factor, the weld beads are sometimes left unfinished as part of the design. For this type of treatment, inert-gas-shielded welding should be specified because it leaves a smoother, spatter-free job. Simple brushing or electropolishing will usually clean the weld

adequately. In some cases, pickling with 10-15% nitric acid–1½% hydrofluoric acid may be preferred. Always specify thoroughly rinsing into clear, warm water after acid treating.

Many stainless products are completely finished after they are made. The designer, in this case can specify the degree of polish he wants. Working with the shop, he can select various combinations of abrasive polishing, buffing and coloring operations. Having established, by trial, a procedure that yields a satisfactory finish, the shop can repeat the routine as often as required.

There is no generally accepted nomenclature that will describe shop finishes adequately. Therefore, if it is impractical to arrive at a satisfactory finish by trial, the designer should use samples which can be matched by the shop that does the finishing.

ELECTROPOLISHING, which is a reverse electroplating operation, is the ideal method of cleaning and polishing intricately shaped stainless parts and assemblies. It has been used most successfully on wire strainers, springs, racks and the like.

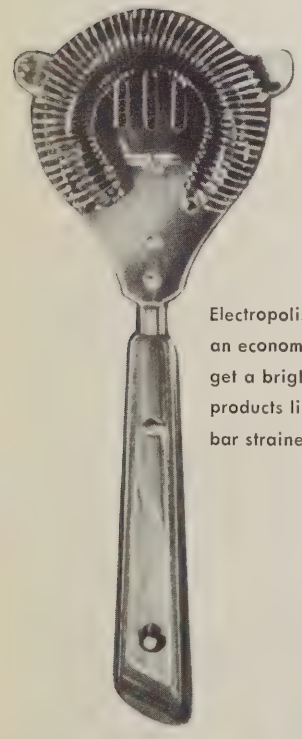
Very little metal is removed during electropolishing, so that any deep scratches will not be cleaned up or masked.

Some plants do their own electropolishing, but this process–like plating–requires special knowledge and experience. Hence, there are commercial electropolishers who do job-lot work, and the practice of sending parts out for electropolishing is very common.

APPLIED COATINGS, such as paint, enamel, etc. can be specified on stainless wherever they are needed.

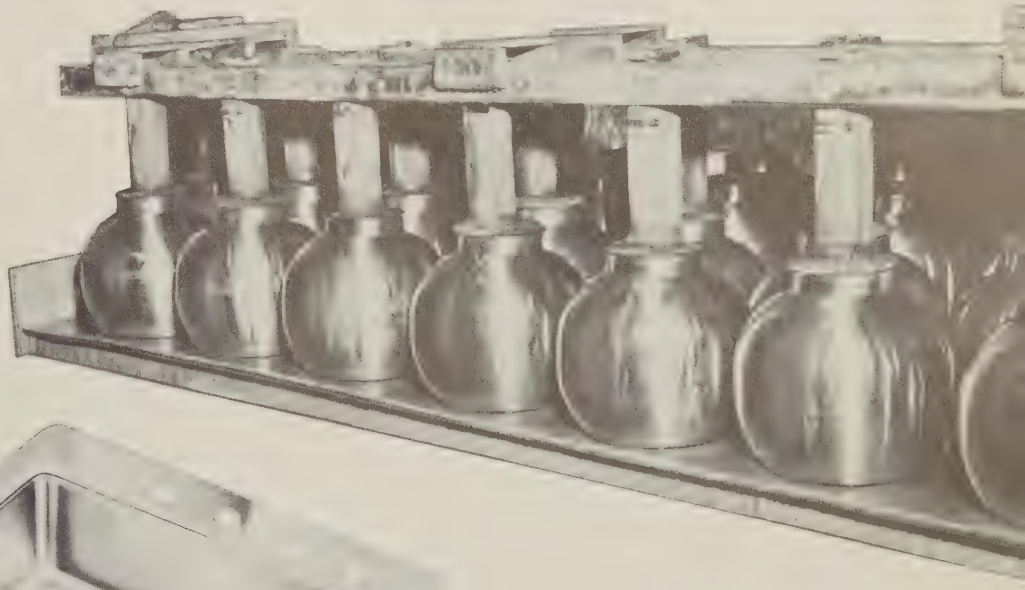
Signs are painted on stainless. Etched nameplates are filled with pigment to afford a color contrast. When the metal is well cleaned and a good paint bond established, excellent service life can be anticipated, because corrosion products don't form under the paint to loosen it.

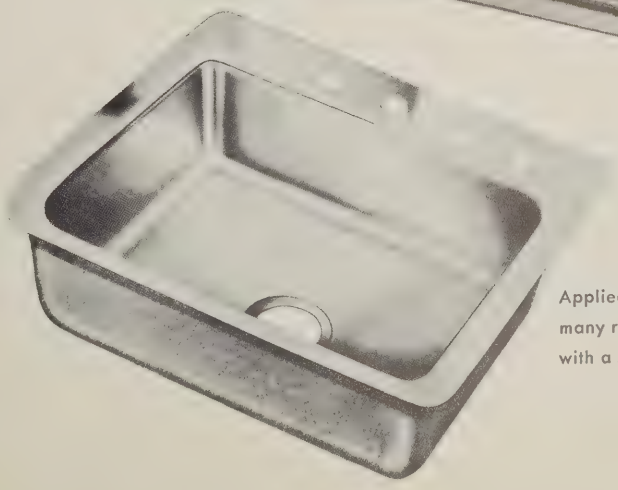
Sound-deadening and insulating material are frequently applied to back sides or interiors of stainless cabinets and the like. The undersides of stainless steel sinks, for example, are often so treated.



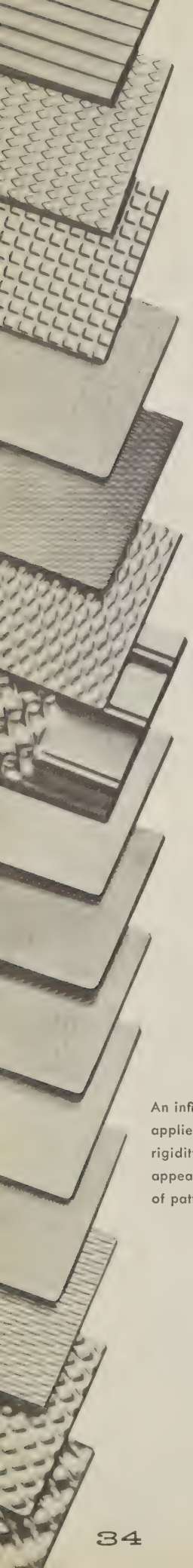
Electropolishing is an economical way to get a bright finish on products like this bar strainer.

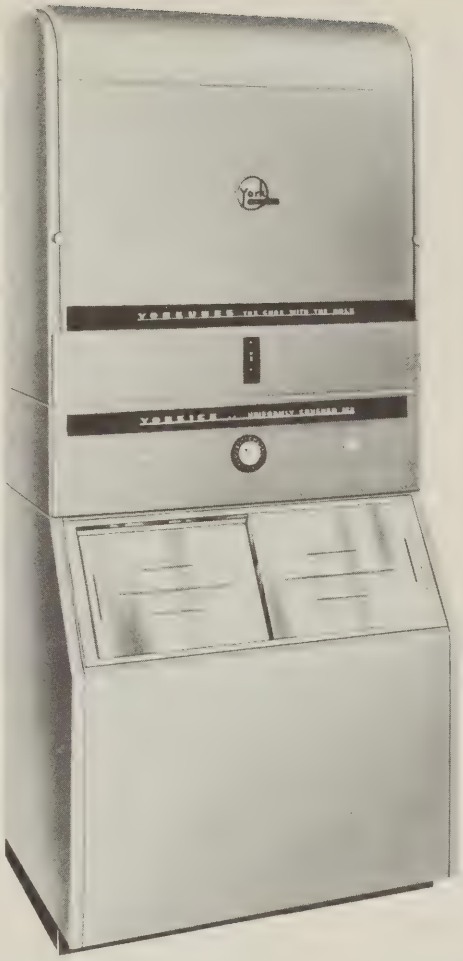
No mechanical polishing is needed on the inside of these coffee-maker flasks. The inner weld bead of the girth seam is cleaned adequately by electropolishing inside the flasks. This picture shows the electrodes immersed in the electrolyte.





Applied coatings are used for many reasons. This sink is covered with a soundproofing material.





An interesting application of textured stainless is illustrated by this commercial ice-cube machine. A textured chute reduces adhesion and permits the cubes to slide more easily.

TEXTURES ON STAINLESS can be obtained by special rolling techniques. The patented, licensed process known as "rigidizing*" employs mating rolls, each of which carries an engraved pattern. It is also possible to put a pattern on flat polished stainless from one engraved roll when the metal is backed up by a smooth roll. By another process, pairs of sheets are rolled with burlap, screening, wood chips, or some other material between them. Both inner surfaces retain the patterned texture of whatever material is employed.

Among the design reasons for using textured stainless, the most frequently decisive one is to break up bright reflection patterns. Occasionally an attractive design can be worked out by combining polished stainless, textured stainless and other materials like porcelain-enameled steel and plastics.

In addition to cutting down brightness by diffusing reflected light, many stainless textures have the virtue of being practically "doodle-proof." They are used, for examples, in telephone booths and on the backs of bus seats for this reason.

Some hardness is imparted when a pattern is rolled into a chromium-nickel stainless. This gives the piece more strength, and the pattern itself may also be designed to stiffen and strengthen the metal along several axes of bending.

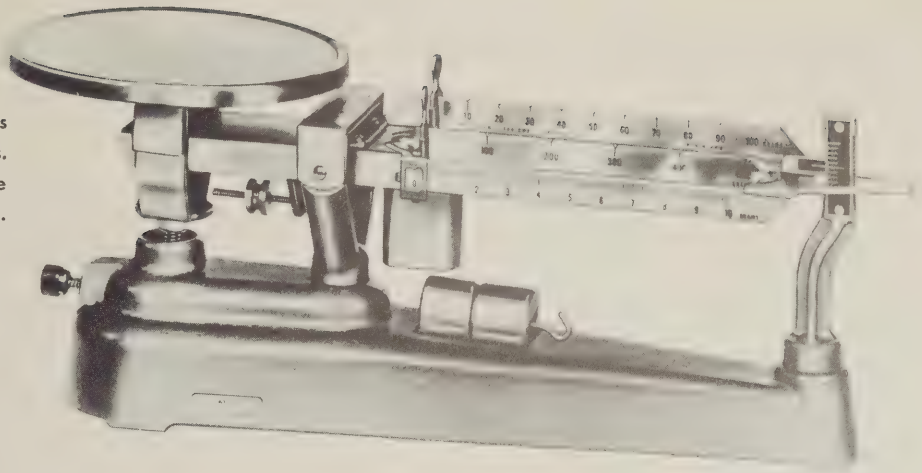
PORCELAIN ENAMEL can be applied to stainless steel. There are several things that can be done with fired enamel on stainless that are impractical or extremely difficult on any other metal.

Very thin, translucent enamel can be applied, so that the reflective glint of the metal tends to show

* Process patented by Rigidized Metal Corporation

An infinite variety of patterns can be applied to stainless to improve its rigidity and to add interest to its appearance. At left is a small sample of patterns commercially available.

Bus seat backs are made of "Rigidized" stainless to give better mechanical properties. Also, the textured surface is "doodle-proof."



Laboratory equipment is traditionally made of stainless. Etched or engraved scales are permanent and easy to read.

through. Intermittent designs or patterns can be made with color on only part of the piece. All or part of a patterned stainless surface can be colored with porcelain enamel. This is done by wiping off some of the porcelain frit before the piece is fired, then buffing it lightly afterward. The metal shines through at the projections, and the colored enamel fills the recesses.

In contrast with porcelain enameling of other metals, this is purely decorative. As it may cover only part of the surface anyway, the enamel does not need to be applied in thick coatings or with meticulous care, which would be required to prevent pin-hole flaws if the metal depended on the coating for protection. The high-temperature strength of stainless also makes it unnecessary to bother with elaborate precautions to prevent warping or sagging of the part during firing.

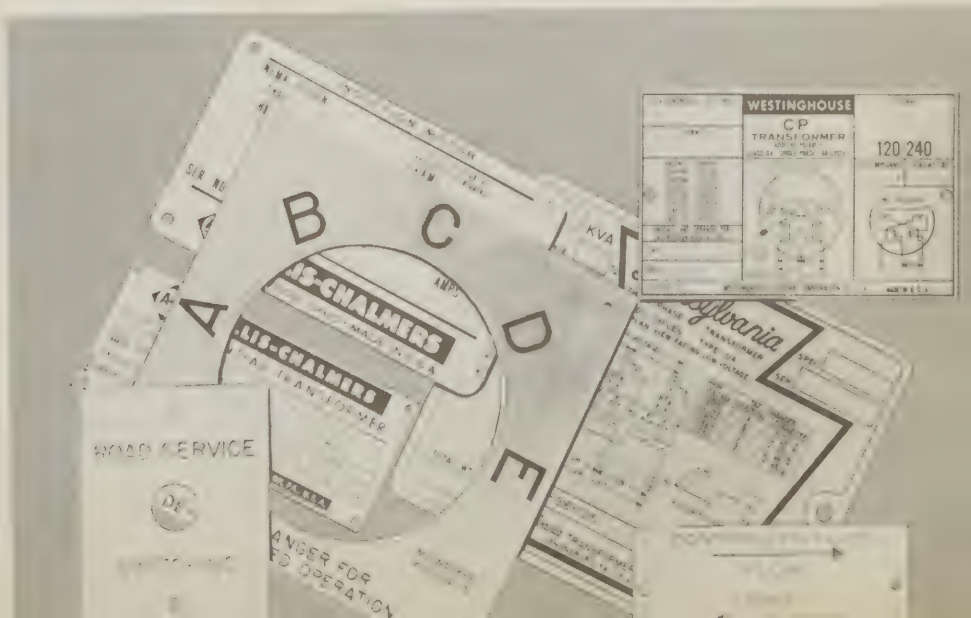
Many styling effects are possible. Either the reflective sheen of the metal or the color of the enamel can dominate—or in-between hues that vary over a single piece can be achieved.

DARKENED, COLORED AND ETCHED surfaces are produced on stainless steel. Heat, chemical treatments, or a combination of both, will affect the surface oxides on the metal, which normally are so thin as to be invisible.

A dull, black surface can be produced with excellent abrasion resistance. One blackening process features photoselectivity, so that halftone pictures can be produced directly in the metal surface.

Orange-yellow colors have been achieved by chemical means, but lack of uniformity has limited any widespread development of this process.

Etched stainless nameplates have been extremely popular for many years, and they continue to grow more so. The etching job itself remains a specialty, however, because the use of chemicals strong enough to attack stainless steel requires a considerable amount of experience. Designers merely depict the nomenclature or artwork required, specify the depth of etch (normally .002 to .010 inch), note the color of paint filling, and have the parts purchased from a firm that specializes in such work.



Nameplates and instruction plates don't have their information "polished off" if they are made of stainless.

Designing for corrosion resistance

Stainless keeps this hot-meal holding and serving kit attractive and cleanable because its surfaces will neither chip nor rust.

The choices a designer makes to achieve corrosion resistance and to make the product easily cleanable have an effect on each other. Selecting the right type of stainless for the environment prevents corrosion and thereby makes cleanliness possible. But, conversely, the nature of stainless steel is such that cleanliness will always be a tremendous aid to the metal in resisting corrosion.

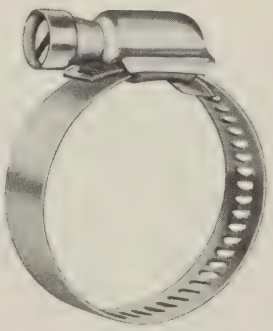
Inasmuch as many design features can help or hinder cleanliness in service, therefore, they also have a bearing on corrosion resistance.

SELECTING A STAINLESS TYPE. In considering corrosion resistance it helps to use the performance of Type 302 as a starting point. This 18-8 stainless is widely used, and it has served successfully in a great number of familiar environments.

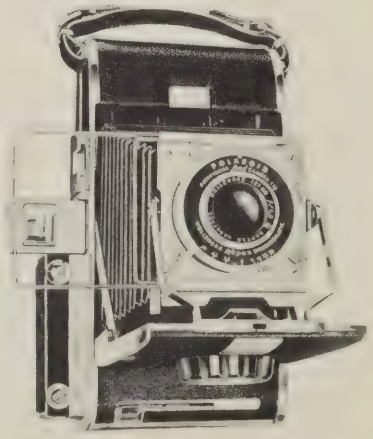
Most people have seen 18-8 stainless in everyday applications like kitchen pans, store front trim, restaurant flatware, lunchwagon backbars and hoods, and many other places. This stainless grade does a consistently good job in such food-handling and architectural situations. As a matter of fact, it is more stainless than it needs to be in most of these applications.

Type 430 stainless is nominally a 17-per cent chromium type, although the range is wide—14 to 18 per cent. This grade is almost as resistant to

An electric grill combines a stainless exterior with cast aluminum cooking surfaces.



Stainless clamps give good service in corrosive environments where plastic pipe and tubing are used.



A stainless roller inside this one-minute-picture camera stays clean and smooth in contact with developing chemicals.

and easy cleaning

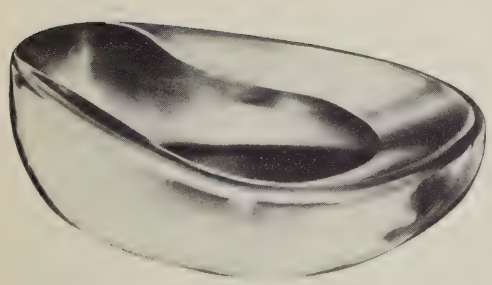
corrosion in most environments as 18-8 stainless, especially when its chromium content approaches the upper limit of 18 per cent.

Type 430 stainless has been widely used during emergency periods of nickel shortage for applications that were formerly filled by Type 302. Both Type 302 and Type 430 have ample reserves of corrosion resistance in the common environments, so that these substitutions have been generally successful.

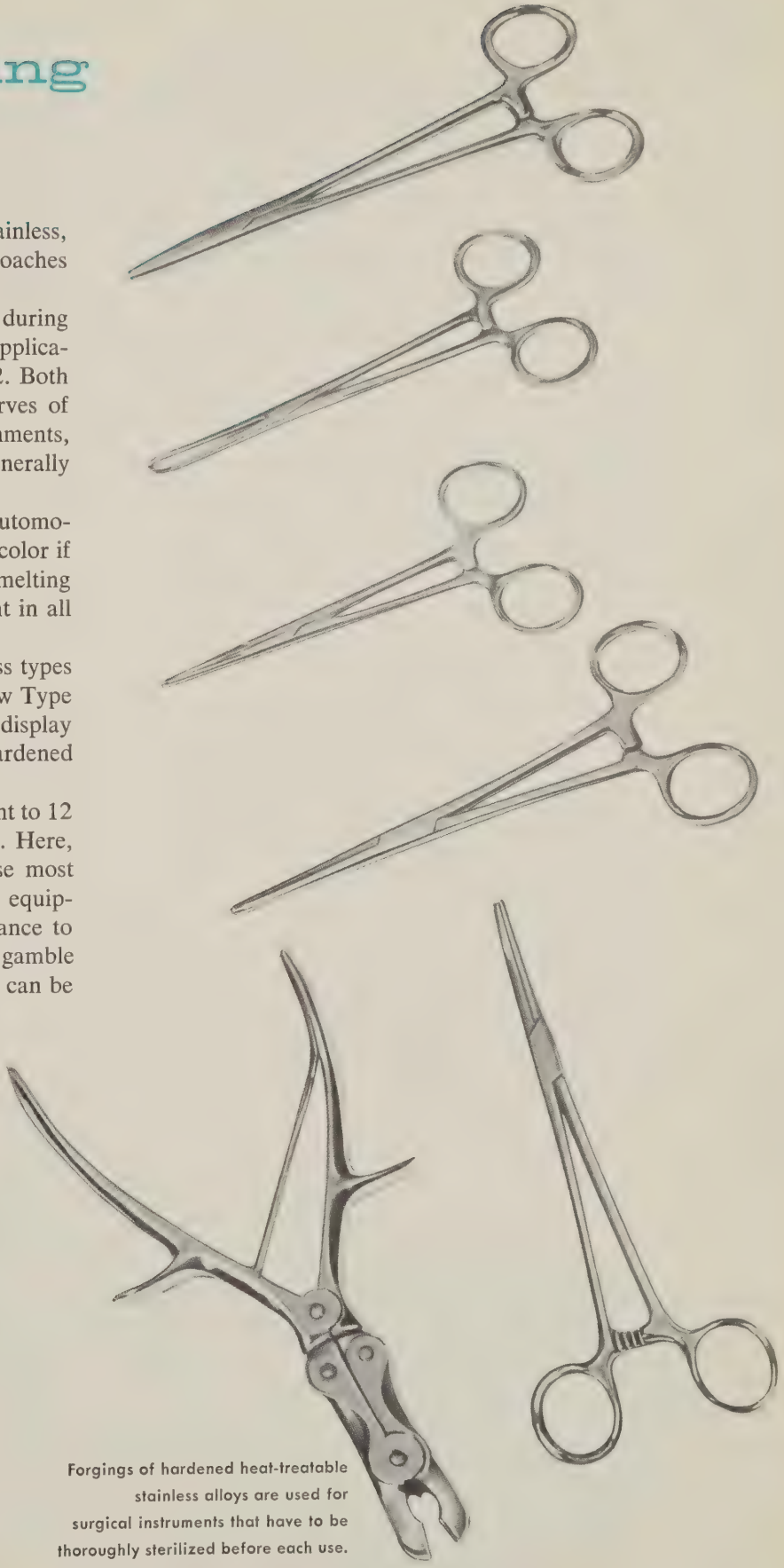
The formed brightwork trim on many automobiles is Type 430 stainless. It may pit or discolor if left exposed for long periods to salt used for melting ice on roads and streets, but will stay bright in all weather when washed occasionally.

The high-carbon, "cutlery grade" stainless types that are hardenable by heat treatment follow Type 430 in resistance to corrosion. They do not display their full resistance except when in the hardened condition.

Going down the scale of chromium content to 12 per cent, we have Type 410 stainless steel. Here, there are few household examples, because most applications are for machinery and process equipment. This type of stainless exhibits resistance to corrosion. Yet Type 410 is probably a safer gamble in equipment for industry where conditions can be



The lowly hospital bedpan utilizes stainless steel's qualities of the utmost—its cleanability, freedom from corrosion, formability and long, non-chipping service life.



Forgings of hardened heat-treatable stainless alloys are used for surgical instruments that have to be thoroughly sterilized before each use.

controlled than in some consumer product that may be abused occasionally.

Now, moving upward in corrosion resistance from Type 302, it is generally more fruitful to go to a molybdenum-bearing stainless than to those with high chromium and nickel. Thus, Type 316 serves under conditions that would be too severe for Type 302. Marine or salt-spray seacoast environments, photo-lab developing equipment and many industrial applications subject to severe corrosive attack call for Type 316.

For simplicity, we can use the five alloys selected as reference points in the following table. Their near relatives, from a corrosion standpoint, are listed below them.

Nominal Content	12 Cr	17 Cr		18-8	18-8, Mo
		Heat-treatable	Non-heat-treatable		
Reference Type	410	440	430	302	316
Related Types	403 416 420	440A 440B 440C	430T 430F	303 304 305 321 347	317
Typical Environment	Coal handling, Pumps, Valves	Cutlery, Surgical instruments, Anti-friction bearings	Architectural interiors, Automobile, Combustion chambers	Foods, Kitchen, Exteriors	Saltspray, Textile & paper machinery, Photography

CORROSION RESISTANCE IS DIFFICULT TO PREDICT. The more experience metallurgists gain with the performance of stainless, the more reasons they find for not making specific rules about it. The rough table above gives a designer a general idea, in terms of his everyday experience, of what he can expect from a few common stainless types made into everyday products.

Beyond this, it is not prudent to use logical deductions without specific testing or experience. The reason is not that accurate data on stainless alloys are lacking. It is because the infinite variety of possible environments and service conditions can yield a bewildering array of performance stories. Minor variations of impurities in a corrodent create violent differences in the way stainless behaves.

Best design practice is to select stainless alloys on the basis of field experience.

The metallurgists and engineers of your steel supplier can offer helpful guidance, too.

MAKE IT SMOOTH, AND ROUND THE CORNERS. Smooth stainless resists corrosion best. Surface finish has a controlling effect on whether cleanliness is possible at all. If there are places that catch dirt, this may lead to selective concentration of corrosive materials and eventual pitting. A No. 4 sheet finish is considered the standard treatment for corrosion resistance.

Rounded interior edges and corners have become conventional in the design of stainless tanks and vessels. This concession to easy washing and rinsing is the result of experience. Sharp corners, cracks, crevices and rough places are dirt gatherers. Dirt that gathers and remains in the same place all the time can cause stainless to corrode under certain chemically reducing conditions.

Inasmuch as such conditions cannot always be predicted or controlled, the designer's best recourse is to make his product as smooth as possible wherever food, pastes, cleaning preparations, dirt, detergents or process chemicals settle and partially dry out.

PASSIVATION MAY BE SPECIFIED. When a stainless steel is subjected to reducing chemicals, its inherent resistance to corrosion is impaired. Normally, oxygen in the air or in solution in rinse water is sufficient to restore its resistance if the reducing conditions are intermittent. For best performance, the balance can be pushed all the way toward maximum corrosion resistance by immersing or swabbing the stainless with nitric acid—a highly oxidizing reagent.

The nitric acid treatment is called passivation. A designer can specify that an all-stainless product be passivated after fabrication if experience proves it necessary. This treatment does another desirable

thing; it removes any cuttings or tool chips of ordinary steel that might otherwise remain on a stainless surface to create rusty spots later. Nitric acid is also useful as a cleansing agent.

If the assembly has iron, steel or copper alloy parts, these should not be exposed to nitric acid even momentarily.

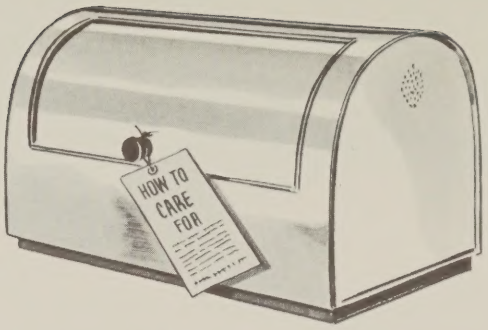
INSTRUCT THE USER OF THE PRODUCT. Stainless steel can stand regular use and a good deal of abuse without trouble. Still, there are cases where staining or pitting may develop because of ignorance of the basic nature of the material.

Without detracting from the merits of your product or the material, a few instructions on care and use can be passed along on a tag or slip of paper with the product.

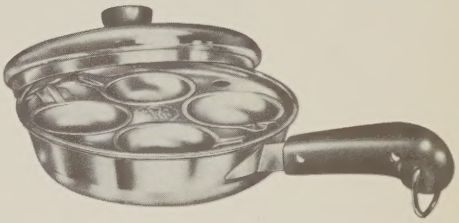
The only points to cover will usually be:

1. Clean with soap or detergent and water.
2. Rinse or wipe off occasionally.
3. Don't leave for a long time in contact with any stagnant, moist mixture.
4. Use a fine abrasive, if desired, for scouring.
5. Don't use ordinary steel wool; only stainless steel wool or scouring pads.

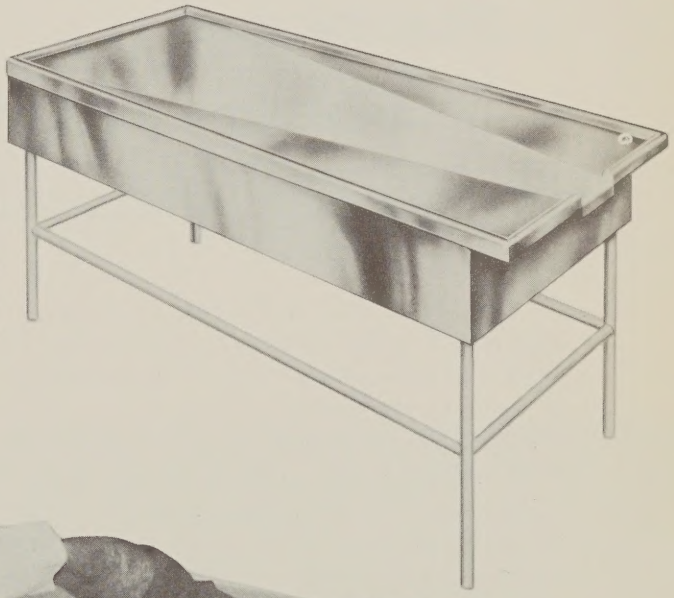
Any special hazards peculiar to the individual product can be added.



A tag on your product with instructions for its use and care will be appreciated by your customers.

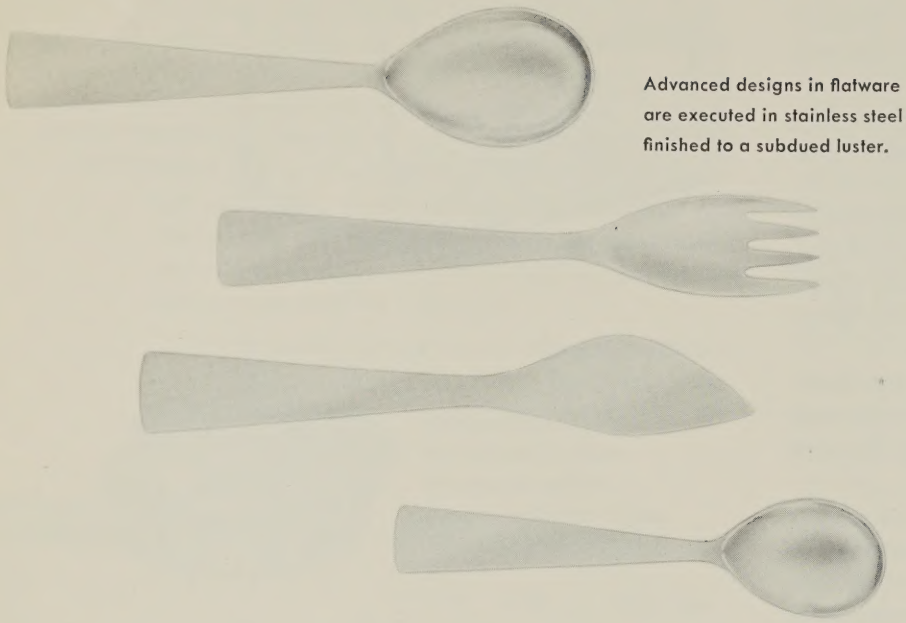


Type 302 stainless is familiar to most people as having practically perfect corrosion resistance under household conditions.

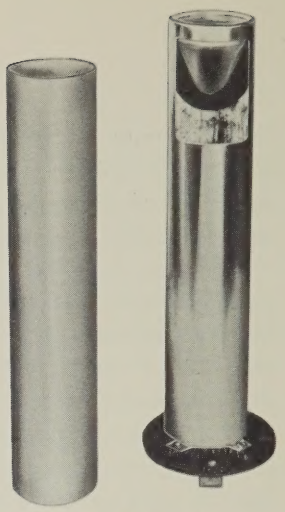


This photo-lab tray has working surfaces of Type 316 stainless. Its extra margin of corrosion resistance over Type 302 is often helpful where chemicals are handled.

Mill-finished sheets are shipped carefully packed with paper between them to assure cleanliness and freedom from marring or abuse.

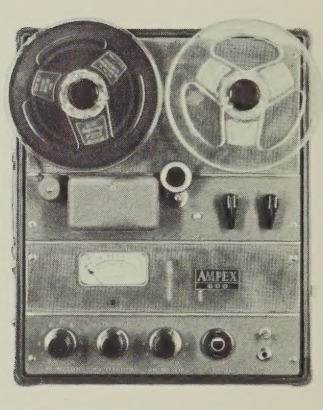


Advanced designs in flatware are executed in stainless steel finished to a subdued luster.



Stainless tube, left, is pierced and polished, right, to make a decorative automobile exhaust tail pipe.

Remove design limitations by using stainless



Chromium-nickel stainless is non-magnetic—a property that let the designers of this tape recorder put a handsome stainless top panel on the unit.

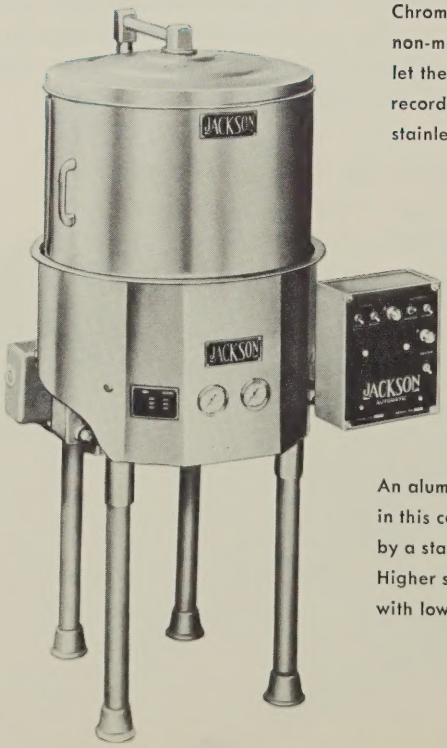
Stainless sheets, strip and tubing are prefinished materials. They don't need painting or plating. The metal is used thin because it is strong and requires no corrosion allowance.

WHEN THE TIME COMES TO PLAN FOR NEW MODELS—new designs, consider stainless.

Have complete cost estimates run up to find out what expensive operations can be eliminated when stainless is used. See how the product can be made lighter, cleaner, easier to make. Even find out how much you save in packing and shipping costs with a lighter product. Estimate the saving in reduced service complaints and reduced breakage.

Many forward-looking designers and engineers have come up with break-even prices despite the fact that stainless usually costs more per pound than alternative materials.

You may find that it's easier for you to feature stainless economically than it would appear to be at first glance.



An aluminum casting was replaced in this commercial dish washer by a stainless stamping. Higher strength was obtained with lower weight.

. . . to answer your specific questions

Much of the material in this book is necessarily general. Specific data will be needed as problems come up. In many cases, the answers to your problems are very likely to have been worked out already by others doing similar work.

For help, feel free to consult fabricators of stainless steel components, the steel warehouses that handle stainless, the steel producing companies, and . . .

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